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INTRODUCTION.

In contradistinction from the year 1920, which was marked by considerable development of the Institute both as regards staff and plantations, 1921 has relatively little to show in those directions. The necessity for strict economy during the present period of general financial difficulty has applied to research stations as elsewhere; as a result the chief problem during the year has been the maintainance of work already in hand without exceeding income rather than the continued development of the Station. Making allowance for inevitable minor capital expenditure this has been fairly well accomplished, although progress in certain lines of work has been slowed down in consequence.

A further marked increase in the volume of Advisory work dealt with has to be recorded, and the effects of this on the research activities is indicated below. While existing conditions continue the Station cannot undertake an increased amount of outside work.

A novel departure from the normal work of the Station resulted from the holding of the Imperial Fruit Show at the Crystal Palace last autumn. In order to illustrate as completely as possible the various uses of the apple the Ministry of Agriculture, in conjunction with the " Daily Mail " authorities, decided to arrange for demonstrations of cider-making to be given daily throughout the Show. After negotiations with the National Association of Cidermakers the Institute undertook the whole responsibility for the demonstrations, the former body bearing the expense involved. Great interest was aroused by them among visitors to the Show and it is unquestionable that the cider industry has already derived material benefit.

Staff.—The only Staff changes to be recorded for the year are the additions caused by the arrival of Mr. F. Summers, D.S.O., M.C., M.Sc., Plant Physiologist to the Station, and Mr. W. H. Neild, Experiments Officer and Recorder, to take up their appointments, which were announced in last year's Report.

For the first half of the year Miss Scott and Miss Watson, of the technical members of the Campden Experimental Factory Staff, were stationed at Long Ashton to investigate certain problems of fruit preservation, in collaboration with Mr. Grove.

During the summer Mr. Wiltshire was absent from the Station for several weeks, during which he made a tour through Holland and Belgium and subsequently visited Paris, to study the phytopathological work in progress in those places. The cost of the

tour was met by the award of a Travelling Fellowship by the Ministry of Agriculture and Fisheries.

Land and Plantations.—Since the considerable extension of the fruit plantations recorded in last year's Report, development work in this direction has been restricted. This policy has been deliberately adopted on account of the necessity of limiting expenditure during the present period of financial difficulty. A few small plot experiments have been started and the establishment of a new cider and perry orchard is being proceeded with gradually; otherwise little is being done towards the formation of new plantations beyond the continued preparation of land taken in hand a year ago.

Buildings.—For financial reasons also it has not been possible to undertake the provision of additional buildings, which are much needed. The most urgent case, that of a house for pot culture experiments, has been met by an improvised temporary structure, which is neither large enough for requirements nor suitable for the conduct of the work under efficient conditions.

General.—The chief development of the year has been the arrangement for the transfer of the Campden Experimental Factory for Fruit and Vegetable Preservation to Bristol University, under which operations there in future will be directed from Long Ashton, and constitute an extension of the work of the latter. Hitherto the factory has been conducted directly on behalf of the Ministry of Agriculture and Fisheries by a Committee appointed by the Ministry, aided by grants from the Development Fund.

In presenting the following Report on the research work for the year, reference must be made to the very serious effect on the research activities of the Station caused by the increase in the calls on the time of the Staff resulting from the rapid development of the Advisory side of its work since the termination of the war. Applications for help and advice come mainly from those directly engaged in the industries which the Station is designed to assist by research and it is therefore not only difficult but frequently impolitic to refuse to give help where it could be rendered. On the other hand an enquiry of that kind generally involves immediate attention if it is to be effective; consequently, research in hand at the time inevitably suffers, in some cases irretrievably for the season. The situation which arises from the lack of assistant staff in the various branches of science with which the Station is concerned threatens to disorganise research to a most serious extent; it is difficult to see a satisfactory remedy if additional staff appointments are not sanctioned.

There remains the pleasant duty of recording once more the part played by the administrative and assistant Staff in the conduct of the work of the Station. During a period when economy has been urgent they have spared no effort to maintain it at an efficient standard.

STUDIES ON ROOT DEVELOPMENT.

By B. T. P. Barker.

The account given in the Report for 1920 of root formation in newly planted trees showed that, in the case of apple trees worked on the English Broad-leaved Paradise stock (Malling Type 1) and grown under the local conditions of soil and climate at the Research Station, the young tree after transplantation produced practically an entirely new root-system, whether that existing at the time of transfer from nursery quarters was retained uninjured as far as possible or subjected to root pruning of various degrees of severity. The conclusion was drawn that under the conditions specified this behaviour was normal for root stock types which were able to form adventitious roots freely, aeration being a dominating factor in determining the actual points of origin of the new roots. The scheme of experiments from which these results were obtained was so arranged that for each of the first five years after the plot was planted there would be available for lifting a batch of thirty trees hitherto untouched since the time of planting, thus making it possible to follow the successive stages in root development. Since it was considered probable that there would arise out of these periodic examinations points which required further investigation, it was decided to include any such new lines of work thus opening up as a part of the general investigation and as far as possible to start them as they occurred without waiting for the completion of the initial programme. Certain points requiring such supplementary investigation were suggested by the results of the first year's root examination, and work upon a few of them was begun a year ago. It is proposed to deal in this article with some of these developments as well as the results of the second year's root examination under the original scheme, since all are more or less directly connected, and to treat it as a progress report on the whole subject.

A.—The Second Year Growth of the Root System After Transplantation.

The results of the examination of the root-systems of the second batch of trees due to be lifted, according to the original scheme, during the winter 1921-22, *i.e.*, at the end of the second season of growth after planting, accord in all respects with expectations

based on the results observed for the trees lifted after one season's growth only which were recorded in last year's Report.

It may be recalled that the trees at the time of planting were divided into five groups, according to the method of treatment of the root. Each group in turn was subdivided into two, in the one case the shoots being pruned at the time of planting and in the other such pruning being omitted. The treatments of the respective groups were as follows :—

Set	I.	Root fibres retained :	tree unrammed :	branches pruned.
„	II.	„ „ „	tree unrammed :	branches unpruned.
„	III.	„ „ „	tree rammed :	branches pruned.
„	IV.	„ „ „	tree unrammed :	branches unpruned.
„	V.	„ „ removed :	tree unrammed :	branches pruned.
„	VI.	„ „ „	tree unrammed :	branches unpruned.
„	VII.	„ „ „	and roots cut : tree unrammed :	branches pruned.
„	VIII.	„ „ „	and roots cut : tree unrammed :	branches unpruned.
„	IX.	Root reduced to short stump :	tree unrammed :	branches pruned.
„	X.	„ „ „ „ „	tree unrammed :	branches unpruned.

Since in all the groups the main result as regards the production of new roots was substantially the same, viz., that a new root-system was produced in the collar region of the tree, little growth taking place elsewhere, it was not anticipated that the additional year's growth would show any marked difference in the progress of root development as between one group and another. So uniform in general character have the results proved to be that one description holds good for all cases.

In general the roots formed during 1920 merely continued the growth in a centrifugal direction from the bole of the tree. The new growth of 1921 was usually partly terminal and partly in the form of new lateral branches of different degrees of strength. Unlike the 1920 results, there was not as a rule much actual new root growth springing from the collar of the tree, the main effort being clearly the extension of the previously formed root-system. Growth in thickness as well as length had occurred, but the behaviour in this respect was curiously variable. Sometimes the 1920 roots were found to have thickened fairly evenly, the root-system then being well-balanced. In other trees the thickening of individual roots varied very greatly, some remaining almost mere fibres, and others becoming relatively coarse and fangy. Where this had happened, there was a tendency for a few of the roots to outstrip the remainder markedly, this leading generally to a pronounced want of balance in the root-system as a whole. It was very noticeable that, where this occurred, almost invariably there was a corresponding lack of balance in the branch system of the tree. Where the branch

system had developed more on one side of the tree than the other, on the former side would be found one or more roots growing much more strongly than any of the remainder. This suggests a relation between natural direction of shoot and root growth associated with a corresponding direct link of the vascular tissues, a point which has sometimes been discussed by growers: and the matter appears worth following further in view of its bearing on the shaping of trees.

The individual sets of trees thus far lifted for examination lend support to the view that the scion variety exercises a material influence upon the root-system. For example, the relatively vigorous Allington Pippin has produced trees with roots coarse and lacking in fine fibre as compared with those resulting from the weaker Stirling Castle, the English Broad-leaved Paradise being the root-stock type used in both cases.

There are only two further features observed which appear noteworthy. The one is the continued relative inactivity of the original root-system away from the collar region, an occasional active root of fair strength being found but in no case any material amount of new root formation. The other is the nearly horizontal course taken by the actively growing roots, which conforms with the observation on root spread of older trees recorded in another article of this Report. Under Long Ashton soil conditions it is evident that rooting is mainly confined to a zone within a foot or so of the surface.

B.—The Second Year Shoot Growth after Transplantation.

No consideration was given in last year's Report to the shoot growth of the trees during the season immediately following transplantation, the facts that some of the trees were tipped at the time of planting and the remainder unpruned and that measurements of growth made during the time when the tree is establishing itself are apt to be misleading, making any comparison at that stage premature. The trees were all winter-pruned at the end of the first growing season as uniformly as the growth of the individual trees would permit. Growth measurements for the second season have been recorded. These are shown in the appended tables.

Although the figures for individual trees do not always vary in the same direction according to the method of root treatment, the averages appear to be sufficiently marked to allow tentative conclusions to be drawn. These, of course, cannot be taken as established until and unless confirmatory evidence is forthcoming from the growth during subsequent years: detailed discussion is best deferred, therefore, until more statistics are available.

Shoot Treatment.	Root Treatment.				
	Fibres retained : tree unrammed.	Fibres retained : tree rammed.	Fibres removed : tree unrammed.	Fibres removed and root cut : tree unrammed.	All roots except stump removed : tree unrammed.
	Average new Shoot Growth per Tree in Millimetres.				
(*a*) Pruned when planted ..	7,782	6,706	8,638	7,734	7,418
(*b*) Unpruned when planted	5,263	6,118	5,771	5,850	5,440
Average (*a*) and (*b*) ..	6,523	6,412	7,205	6,792	6,429
	Average Girth at 1 Foot above Ground Level per Tree in Millimetres.				
(*a*) Pruned when planted ..	80	75	81	75	72
(*b*) Unpruned when planted	67	73	68	71	67
Average (*a*) and (*b*) ..	74	74	75	73	70
	Average Number of New Shoots Produced per Tree.				
(*a*) Pruned when planted ..	21	16	19	18	19
(*b*) Unpruned when planted	16	12	12	13	13
Average (*a*) and (*b*) ..	18.5	14	15.5	15.5	16
	Average Length of New Shoots per Tree.				
(*a*) Pruned when planted ..	362	409	464	430	389
(*b*) Unpruned when planted	304	507	498	464	404
Average (*a*) and (*b*) ..	333	458	481	447	397

The first conclusion is that shoot growth of the established tree is relatively little affected by the nature of the root treatment given at the time of planting. There are 30 trees in each group subjected to the same form of root treatment and the average result per tree in each, whether 1921 shoot growth or girth is taken as the criteron, shows no wide differences from the others.

The second conclusion is that the average effect of tipping the shoots at the time of planting, whatever the manner of treatment of the roots, is an appreciably greater amount of new shoot growth during the second season and, to a lesser extent, an increase in girth as compared with non-pruning.

The third conclusion is that while there is a tendency for a greater number of buds to grow out into new shoots in the case of the trees treated normally at the time of planting, the average individual length of such shoots is materially less than in any of the other cases. The difference is sufficiently marked to call for notice and the circumstances do not suggest it being a chance result. Whether or not this feature

is of ultimate detriment or benefit to the tree time alone can show.

Considering the wide differences in root treatment, the absence of any great variation in the average amounts of new shoot growth would have been very surprising had not the results of the examination of the 1920 root growth, showing that in all cases a new root-system was produced, prepared for this. For the case of the particular root-stock type used in these trials (the English Broad-leaved Paradise) Pickering's view that it is unnecessary when planting a tree to take care to preserve the finer fibrous roots is thoroughly confirmed. Whether one can go a step further and contend that the removal of those roots is beneficial is a point which calls for more investigation. The shoot growth figures here quoted support that idea, especially in the cases where the trees were pruned at the time of planting, but the difference in favour of fine root removal is not sufficiently marked to justify a conclusion of that sort without confirmatory evidence from other trials. The more drastic treatment of removal of the coarser branch roots as well as the finer fibrous material is, according to the figures, somewhat too extreme, although it cannot be said to have seriously hindered the growth of the tree.

The results which are most difficult to interpret are those of the total shoot growth of the trees rammed at the time of planting. The experiments of Pickering on ramming at Woburn and several other centres indicated that such treatment produced increased shoot growth, especially marked in the second season following planting. The trials under consideration fail to confirm those results, and it may be mentioned here in passing that two previous trials on ramming made at Long Ashton, hitherto unrecorded, have similarly failed. It is, however, very curious to find that, although the shoot growth of the rammed trees pruned when planted is relatively very much below that of all the others similarly pruned, it is higher for them when unpruned at planting than any of the others in the unpruned series.

Before passing from this part of the subject reference should be made to the nature of the weather conditions during the season following the planting of the trees. The latter were not planted until March, 1920. Dry conditions prevailed until the middle of June, after which the remainder of the growing season was decidedly rainy. The late planting followed by several weeks of drought cannot be regarded as favouring the treatments involving more or less severe root mutilation. Indeed, the trees in those groups probably were handicapped somewhat by the weather conditions; if so, the features to which attention has been directed would presumably be intensified in an average season rather than the reverse. An even more trying season was experienced in 1921, when the drought was practically continuous

throughout, and its effects were marked on the new series of root treatment experiments to which reference will be made in a subsequent Report. The point it is desired to emphasise is that the results in such trials must be affected to some extent by the weather, repetition being therefore desirable to eliminate the factor of weather influence.

C.—Root Development During the Growing Season.

As a part of the general investigation on the influence of the root-system upon the growth and behaviour of the tree the question of the time and rate of root growth during the growing season obviously arises. When the work on the behaviour of the root-system following the transplantation of the tree was started, the general description and first results of which were recorded in last year's Report, an attempt was made to observe directly the course of root growth ensuing after the different methods of treatment of the root-system previous to planting. The trees were grown under the water culture method, which permitted a general view of the roots as required. The article referred to contains an account of the observations made, these sufficing to show the positions in which new roots originated but little else to which any importance could be attached on account of the obviously unfavourable conditions for root growth under that method of culture.

A further attempt was made during the 1921 growing season on different lines, which proved much more satisfactory. The head was removed from a 30-gallon cask, which was placed on end, and the trees to be kept under observation were suspended above the opening in such a position that the roots hung within the cask a foot or so below the rim. A sprinkler arrangement was inserted in the centre, attached to a siphon kept regularly supplied with a nutrient culture solution. At regular and frequent intervals—about every three to five minutes—a fine spray was produced within the cask by this device and the roots were so placed that they were well moistened by it. In this way they were kept constantly wetted with a nutrient solution and never allowed to become dry, while at the same time by being suspended in air they were much better aerated than if immersed in liquid. The excess fluid drained freely from them and collected at the bottom of the vessel, from which it was removed at intervals before it reached the level of the roots. It was possible to deal with six trees in one cask, those being three-year-old Bramley's Seedling and Lane's Prince Albert apples worked on Paradise stocks of the Malling types III and V. The experiment was started in April and continued in regular working order until December. The method being under trial for the first time no attempt was made to take quantitative measurements of the rate

of root growth in view of the probability of adjustments being necessary from time to time to secure more efficient working. In point of fact few adjustments were needed and the results for a first trial may be considered very fairly satisfactory. Weaknesses were disclosed during the course of the season which will need to be remedied in future trials if growth equal to that of trees grown in soil or sand pot cultures is to be obtained: but, except for the amount, there is no reason to think that the general course of either root or shoot growth obtained differed in character from that occurring under the latter conditions. The method is certainly much superior to the water culture method for apple trees and, if leaf appearance may be taken as a guide, is capable of promoting healthy and practically normal growth.

Since it is proposed to take detailed records of the rate of root growth during the coming season and definite data will accordingly be available for consideration, it would be premature here to do more than describe generally the main sequence of events as observed. The beginning of new root formation was visible towards the end of April, before the opening buds had expanded. The new roots were formed at various places on the old root-system and not confined to any particular region. During the next few weeks they increased relatively rapidly in length and fresh ones made their appearance frequently. Then followed a phase extending over midsummer until well into July, during which both extension root growth and new root production was comparatively quiescent. This gradually was succeeded by a more active period again, which was maintained until the conclusion of the season's observations some time after leaf-fall. This late summer and autumnal root activity was very marked and by far the greatest increase in root length throughout the season occurred during that part of the year. Stated in relation to shoot growth there are three well defined phases during the growing season. The first, which is not of long duration, is marked by rapid root and shoot growth occurring simultaneously. This gradually passes into the second, during which shoot growth is still active and root growth relatively inactive, a condition which is, perhaps, most marked about midsummer. Later, as shoot growth slackens, root activity greatly increases, the balance between the two in this third phase being directly the opposite of that obtaining during the second.

In this connection a further series of observations may be recorded, since they appear to bear very closely on this question of the relation between root and shoot development and are very suggestive as to the processes going on within the plant causing this relation. They arose from experiments on the effect of ringing on the growth of black currants, which were made in the first instance as a part of another entirely distinct investigation which need not be

considered here. In these experiments, which were conducted on two-year-old black currant plants grown in pots in sand, in some cases with and in other cases without the addition of nutrient solution, a ring of bark about $\frac{1}{3}$ of an inch in width and extending as deeply as the wood was removed from the main stem of each plant brought under treatment, just as in the ordinary operation of "girdling" or "ringing," which has been described in the Annual Report for 1919, in the article dealing with "Notching and Ringing of Apple Trees." The inner tissues of the shoot exposed by the ring, together with the parts of the stem immediately above and below, were kept moist after ringing by being wrapped loosely with a small cover of cotton wool kept constantly damp by a regular drip of water from a vessel situated immediately above. In each set of experiments other plants were used as controls, these being unringed but otherwise similarly treated as regards the moistening of the zone of the stem corresponding to the position of the ring in the other cases. The experiments were started in April, 1921, about the time when the plants were coming into full leaf and before much actual shoot growth had taken place. They were conducted in a cool greenhouse. The point of interest here being the root growth which occurred in the neighbourhood of the ring as a result of the moist conditions maintained in that region, no detailed attention need be given to the behaviour of the plants in respect of shoot growth.

The ringed plants by the end of ten days were showing much activity in the way of adventitious root production in the neighbourhood of the ring. Immediately below the ring and bursting through the tissues of the bark of the stem kept moist by the water drip the growing points of many roots were plainly visible, these being easily distinguishable by that time from the tissue out-growths of the lenticels which also occurred simultaneously under such conditions and which a few days earlier were not sufficiently developed for their nature to be determined with confidence. Just above the ring, but a few days later than those below, other roots similarly arose. In the case of the unringed control plants no roots developed in the moistened region until three weeks after the experiment was started. By that time the new roots of the ringed plants had in many cases grown to over an inch in length. Production of these adventitious roots only occurred in the zone of the stem kept moist by the cotton wool wrapping, this applying both to the ringed and unringed plants and showing that moist conditions are necessary.

As soon as these results were obtained a corresponding set of experiments was started with a fresh batch of plants, these in point of time being thus about a month later in the growing season than the first. The treated plants were similar except that they were, of course, a month more advanced in growth, appreciable

shoot growth having taken place. In this instance the results differed widely from the former. While in the case of the controls new roots first appeared in practically the same time as before, those formed on the ringed plants were in this instance not more than a day or two ahead and were confined exclusively to the zone above the ring, none appearing below.

Thence onwards until the end of the growing season similar series on other plants held in reserve were started as soon as the complete results from the immediately preceding set were available. For the sake of brevity a detailed description of each will be omitted, the individual results being so definitely graduated in character and corresponding to a general type that they can as well be considered *en bloc* as separately.

The behaviour was as follows. Until September the unringed plants produced roots in approximately the same time as in the original set, viz., three weeks, there being but a few days difference in the time taken for the appearance of the earliest roots in any set. In the set in progress at the beginning of September, the time taken was longer, four weeks being required, and in addition the number of roots and the amount of growth was distinctly less. In the following series, started September 20th, which proved to be the last of the season, although the drip treatment was continued until November, no roots were formed.

The ringed plants on the other hand, while taking approximately three weeks to show the earliest signs of root formation in the respective series in progress during May, June and early July, exhibited marked acceleration in the subsequent series. The July, August, and early September sets gave root appearance in seven days, and even the last set of the season, beginning as stated in the previous paragraph on September 20th, yielded roots in ten days, notwithstanding that by that time defoliation was proceeding and shoot growth had long since ceased.

Adventitious root formation in the case of these ringed plants thus follows very much the same course as the root growth noted with the apples. It is rapid in the early part of the season, slows down markedly till midsummer and then increases for the latter half of the growing season, till it is as free as in the initial period. The unringed plants differ in that root development is slower in the first instance, remains approximately the same throughout the growing season until leaf-fall begins, when it slows down and finally ceases altogether.

The significance of these results may now be considered. It is suggested that they are correlated with the circulation of organic food reserves within the plant. At the beginning of the growing season the amount of these available is relatively large, representing the accumulation from the previous season's activity. They are

distributed throughout the tree and are available, therefore, in the neighbourhood of any centres of growth which may become active. Hence at that period both shoot and root growth can be sustained simultaneously until they are exhausted. When that happens, the plant becomes dependent on fresh material manufactured in the leaves. The observed facts recorded show the continuance of shoot growth without serious check for some weeks and the reverse for root growth. The inference is that the food elaborated in the leaf is supplying the former at the expense of the latter, presumably owing to its closer proximity. This condition, however, cannot be expected to last indefinitely, since the plant depends on the root for its water requirements and all raw food materials except carbon dioxide; continued shoot growth and leaf development unaccompanied by equivalent root growth must tend to lead to shortage in those respects and to a slackening of aerial growth. This is turn would involve a higher concentration of organic reserves and higher osmotic pressure in the neighbourhood of the leaves, since photosynthesis is constantly proceeding in the latter. The diminished shoot growth then no longer can utilise all while the water supply is limited, and the excess is probably largely translocated downwards towards the roots, which in due course show growth increase as a result.

It is in this connection that the experiments with the ringed currant plants seem particularly instructive. The removal of the ring of bark makes a break in the continuity of the phloem tissues, which are regarded as the main channels for translocation of organic reserves within the plant. In the early part of the growing season adventitious roots were formed below the ring, indicating the accumulation of reserves at that point by the interruption in the upward flow, which is supposed to take place when the season's growth begins. The later series did not show this root production below the ring and the presumption is that such reserves were by that time exhausted. Root production above the ring then occurred instead, pointing to an interrupted flow of reserves coming from above downwards. At first growth there was slow, suggesting very limited supplies: later it increased rapidly implying a greater stock of available reserves. With the unringed currants no such break in the circulatory system was provided: hence the passage of materials past the moistened zone of the bark was uninterrupted and no accumulation occurred there. This probably accounts for root production in these cases being invariably slow and also for the time taken for it being practically uniform throughout the season.

From the beginning of July onwards various supplementary experiments with ringed currant plants were made with the object of ascertaining the manner in which the results would fit in with

the ideas above suggested as to the presence and circulation of reserves within the plant during the growing season. The following results appear to have some bearing on the point.

(*a*) Ringed plants grown in sand kept moist with nutrient solution gave more vigorous adventitious root development than others in sand supplied with water only, especially when a drip of nutrient solution was used instead of the water drip. Generally also the first adventitious roots were formed slightly quicker in the former case. In that case the supply of nutrient solution is doubtless responsible for a greater production of organic material by the leaves, which in turn is reflected in the greater root growth.

(*b*) Similar ringed plants kept during July in darkness from the time of ringing formed only a very few weak roots and these were slower in making their appearance than in any other case. The prevention of carbon assimilation by the absence of light is the cause to which this result must be attributed.

(*c*) A very similar result to that recorded in (*b*) was obtained when all leaves were removed from ringed plants at the time of ringing. These trials were made during July and the plants kept in a greenhouse. By the time roots appeared a small amount of new shoot growth with accompanying young leaves occurred, this not being removed as formed. The root development was somewhat stronger than in (*b*) and was a few days earlier in first appearance, although more than a week slower than with ringed non-defoliated plants. Absence of photosynthesis may be regarded as the cause of the difference in behaviour between the defoliated plants and the latter.

(*d*) Complete removal of all shoots during the current season in addition to defoliation, these being cut right back to the one year old wood at the time of ringing, resulted generally as in (*c*), but with slight acceleration in time or root formation. No appreciable amount of new shoot growth occurred within that period, and possibly this accounts for the rather shorter time required for root production, all the reserves available at the time of ringing being available for the latter.

In spite of the fact that the whole of these observations on currants are concerned with adventitious root production under a very special form of treatment and, therefore, are not directly com-

parable with those recorded for the apple trees, there is such close correspondence in the results as to the degrees of root activity during the various periods of the growing season that they may fairly be considered as intimately related and probably indicative of a general rule applying at least to deciduous shrubs and trees.

While suggesting that the phenomena of root growth during the growing season are associated directly with the circulation of reserves within the plant and that the rate of such growth is closely correlated with the available quantity of these substances, it is recognised that there are many points which require more detailed consideration than space will permit here and that supplementary evidence in various directions is needed before these views can be considered established. The present article, however, does not purport to be more than a progress report; it is hoped that further work now in hand will justify a more complete discussion in due course.

SOME OBSERVATIONS ON THE EXTENT OF ROOT DEVELOPMENT IN MATURE FRUIT TREES.

By G. S. Peren.

On account of the small amount of available data on this subject and the need for fuller knowledge of the extent to which the roots of fruit trees spread it was felt that some useful information might be collected by uncovering and following as far as possible, if not the entire root-systems, at least some of the main roots of trees which, from time to time, have to be removed for various reasons.

A knowledge of the extent and habit of growth of the roots of the various stocks in use should be of considerable use when planning a new orchard and in laying out field experiments, in which it is essential that there should be no overlapping of roots, it would be invaluable.

The following data represent the results thus far obtained.

Example I.

Norwegian Cherry	... Standard tree.
Plot	... VIII.
Variety... ...	... Unknown.
Age	... 15 years.
Span of branches	... On W. side, 7ft. 9in.; on E. side, 12ft.
Vigour	... Comparatively strong.
Length of Roots	... (*a*) Main, 35ft. 10in.
	(*b*) Lateral of (a), 34ft. 3in. (from trunk).
	(*c*) Lateral of (a), 31ft. 10in. (from trunk).
Apex of root from trunk	(*a*) 34ft. 3in.
	(*b*) 27ft. 1in. (Root doubled back; at one point was 29ft. 3in. from trunk).
	(*c*) 27ft. 3in.

The figures given under " Apex of Root from Trunk " represent the distance in a straight line between the farthest point of the root uncovered and the trunk.

The numbers of the plots are stated in all cases for purposes of reference to the soil analyses of the respective plots given below.

Considering the age of this tree, the length of root is considerable. Although not one of our own cultivated varieties, it would appear to substantiate the rule that standard cherries require to be planted 35ft.—40ft. apart for reasons below as well as above ground.

In connection with the length of the roots—and this remark applies to all future measurements given of a similar nature—it was practically impossible to trace the root to its actual apex, the soil being of a comparatively heavy nature; it is considered that approximately one foot should be added to the measurements given to arrive at the actual length of the root.

The following measurements taken give a general indication of the depths at which the roots grew.

Root (*a*)—

Distance from point of origin at trunk.	Depth below ground level.	Distance from point of origin at trunk.	Depth below ground level.
0 in.	6 in.	181 in.	12 in.
29 ,,	9 ,,	208 ,,	16 ,,
39 ,,	10 ,,	238 ,,	10 ,,
90 ,,	8 ,,	266 ,,	12 ,,
111 ,,	12 ,,	286 ,,	10 ,,
131 ,,	13 ,,	304 ,,	8 ,,
138 ,,	7 ,,	358 ,,	13 ,,
145 ,,	10 ,,	370 ,,	18 ,,
157 ,,	15 ,,	394 ,,	19 ,,
166 ,,	13 ,,	430 ,,	18 ,,

From these figures it can be seen that the root was of the surface feeding type, in this respect approximating to the Paradise apple types. The figures for roots (*b*) and (*c*) show the same habit with the exception of the last 24in. of the measured length of root (*c*), which was striking vertically downwards.

In following these roots a number of laterals were encountered, but none of them except roots (*b*) and (*c*) were big enough to be worth following. When compared with branching in the aerial portions of a tree this lack of large branch roots was quite noticeable. Generally speaking, the data obtained merely bear out what one expected to find in the case of a cherry tree of a strong type, namely, considerable length of root of a surface-feeding habit.

Example II.

Apple	... Bush tree.
Plot	... XIV.
Variety	... Bramley's Seedling.
Stock	... Broadleaved Paradise (reputed).
Age	... 19 years.
Vigour	... Fair.
Length of roots ...	... (*a*) 11ft. 4in.
	(*b*) 13ft. 1in.
Apex of root from trunk	(*a*) 10ft. 8in.
	(*b*) 11ft. 4in.

The lengths of the roots are not very great in this case, but this is to a great extent due to the fact that the tree was transplanted at the age of nine years, and so had only been in the site examined for 10 years. Had it not been for this check it is reasonable to assume that the roots would have been very much longer. Some idea, however, can be gained of the amount of "overlapping" of roots that must take place in orchards where strong growing varieties have been planted out at short distances apart.

As regards depth, these roots were quite shallow and typical of the Paradise types, with the exception of the last 27in. of root (*b*), which struck downward at a very steep angle, the farthest point measured being 25in. below ground level.

To give an idea of the general depth of these roots the depth measurements for root (*b*) are given as follows :—

Distance from point of origin at trunk.	Depth below ground level.	Distance from point of origin at trunk.	Depth below ground level.
0 in.	0 in.	103 in.	14 in.
18 ,,	11 ,,	115 ,,	9½ ,,
38 ,,	11 ,,	130 ,,	13 ,,
63 ,,	12 ,,	143 ,,	19½ ,,
85 ,,	15 ,,	155 ,,	21 ,,
97 ,,	13½ ,,	157 ,,	25 ,,

It will be seen from these figures that except for the last 27in., previously mentioned, the depth is shallow and the variation comparatively slight.

In addition, the following measurements were taken of the remaining important roots at a distance of 2ft. 6in. from the trunk.

No.	Diameter approx.	Depth below ground level.	No.	Diameter approx.	Depth below ground level.
1	1/3 in.	10 in.	7	1/2 in.	9½ in.
2	1/4 ,,	5½ ,,	8	1/4 ,,	10 ,,
3	1/3 ,,	5½ ,,	9	1/3	8½ ,,
4	1/2 ,,	4½ ,,	10	1/2 ,,	8 ,,
5	1/3 ,,	5 ,,	11	1/3 ,,	10 ,,
6	1/3 ,,	6 ,,			

The smaller roots are on the average even more shallow than the large roots (*a*) and (*b*).

EXAMPLE III.

Apple ... ... Bush tree.
Plot ... ... VIII.
Variety ... ... King of the Pippins.
Stock ... ... Broadleaved Paradise (reputed).
Age ... ... 19 years.
Vigour ... ... Poor.
Length of root ... ... 10ft. 4in.
Apex of root from trunk 6ft. 5in.

The length of root in this case is very poor, but the tree had never done well and for a long time had been badly cankered: hence its removal.

Distance from point of origin at trunk.	Depth below ground level.	Distance from point of origin at trunk.	Depth below ground level.
10 in.	7 in.	36 in.	19 in.
14 ,,	6 ,,	75 ,,	19 ,,
19 ,,	10 ,,	81 ,,	23 ,,
26 ,,	11 ,,	124 ,,	77 ,,

The root arising at a depth of 7in., there is a tendency for most of the figures to be a little high, but the behaviour of the last 43in. is extraordinary, the root descending in an almost true vertical line, the farthest point measured being 77in. below ground level. The frequent occurrence of behaviour of this type will be discussed later, but it may be mentioned here that this tree was cut down in the Spring of 1920, and so could show no influence of last summer's drought.

Example IV.

Apple	... Bush tree.
Plot	... VIII.
Variety	... King of the Pippins.
Stock	... Broadleaved Paradise (reputed).
Age	... 19 years.
Vigour	... Poor.
Length of root ...	... 13ft. 2in.
Apex of root from trunk	6ft. 8in. (Root doubled back ; at one point was 8ft. from trunk).

Length of root is here again shorter than might have been expected, were it not for the poor condition of the tree which was one of the same row as No. III.

In the course followed the root formed the letter S, the terminal point finally growing in the direction of the trunk.

Depth measurements were as follows :—

Distance from point of origin at trunk.	Depth below ground level.	Distance from point of origin at trunk.	Depth below ground level.
0 in.	11 in.	95 in.	15 in.
21 ,,	14 ,,	103 ,,	18 ,,
36 ,,	15 ,,	131 ,,	13 ,,
54 ,,	20 ,,	142 ,,	14 ,,
74 ,,	18 ,,	158 ,,	10 ,,

In this case again, the root arising at the depth of 11in., the majority of the figures are high, the root having kept to a fair depth for its entire length.

Example V.

Plum	... Bush tree.
Plot	... X.
Variety	... Pond's Seedling.
Stock	... Unknown.
Age	... 16 years.
Vigour	... Fair.
Length of roots ...	... (*a*) 15ft. 10in.
	(*b*) 12ft. 4in.
Apex of root from trunk	(*a*) 12ft. 8in.
	(*b*) 9ft. 4in.

The length of root is short when one considers that some 10-year-old plum trees of several varieties growing in the Station

grounds are throwing up suckers as far as 18ft. away from their trunks. The depth, however, is very interesting, both roots being very near the surface in places. Details are as follows :—

Root (*a*)—

Distance from point of origin at trunk.	Depth below ground level.	Distance from point of origin at trunk..	Depth below ground level.
0 in.	0 in.	86 in.	8 in.
8 ,,	2 ,,	104 ,,	6 ,,
14 ,,	6 ,,	119 ,,	13 ,,
29 ,,	2 ,,	140 ,,	10 ,,
51 ,,	5 ,,	149 ,,	7 ,,
55 ,,	7 ,,	158 ,,	10 ,,
64 ,,	14 ,,	190 ,,	11 ,,
77 ,,	8 ,,		

Root (*b*)—

Distance from point of origin at trunk.	Depth below ground level.	Distance from point of origin at trunk.	Depth below ground level.
0 in.	0 in.	78 in.	12 in.
9 ,,	3 ,,	96 ,,	6 ,,
33 ,,	7 ,,	118 ,,	9 ,,
48 ,,	11 ,,	148 ,,	9 ,,
61 ,,	9 ,,		

The following measurements of the remaining roots at a distance of 3ft. 6in. from the trunk were also made.

No.	Diameter approx.	Depth below groung level.	No.	Diameter approx.	Depth below ground level.
1	1/3 in.	9 in.	8	1/3 in.	10 in.
2	1/2 ,,	9 ,,	9	1/4 ,,	6 ,,
3	1/3 ,,	6 ,,	10	1/3 ,,	10 ,,
4	1/3 ,,	8 ,,	11	3/4 ,,	11 ,,
5	1/3 ,,	10 ,,	12	3/4 ,,	12 ,,
6	1/2 ,,	8 ,,	13	1/4 ,,	9 ,,
7	1/3 ,,	6 ,,			

From these figures it can be seen that in this case the stock has adopted a very surface rooting habit. The tree was planted very shallow in the first place, but there does not appear to be any reason why that should affect the depth of the roots at some distance from the trunk.

Example VI.

Plum	Bush tree.
Plot	X.
Variety	Victoria.
Stock	Unknown.
Age	16 years.
Vigour	Poor.
Length of root	12ft. 5in.
Apex of root from trunk	9ft. 6in.

Two points stood out in connection with this tree; firstly, the shallowness of the root-system, several quite large roots having been cut off at various times by digging with a spade and others showing numerous scars, and, secondly, the habit of striking vertically downwards already met with in the case of the cherry tree, No. 1, and the apple, No. 3.

The root which was followed pursued an absolutely vertical course downwards for the last 33 ins. of its measured length, the apex being 44ins. below ground level in a very stiff clay subsoil.

The depth measurements of this root were as follows :—

Distance from point of origin at trunk.	Depth below ground level.	Distance from point of origin at trunk.	Depth below ground level.
0 in.	0 in.	89 in.	9 in.
23 ,,	5 ,,	104 ,,	12 ,,
40 ,,	7 ,,	116 ,,	11 ,,
53 ,,	7 ,,	149 ,,	44 ,,
71 ,,	4½ ,,		

The following measurements were taken of other important roots at 3ft. 6in. from the trunk.

No.	Diameter approx.	Depth below ground level.	No.	Diameter approx.	Depth below ground level.
1	1/2 in.	7 in.	6	5/8 in.	3 in.
2	1/3 ,,	7 ,,	7	5/8 ,,	4 ,,
3	1/4 ,,	5 ,,	8	1/2 ,,	16 ,,
4	1/2 ,,	11 ,,	9	3/4 ,,	7 ,,
5	3/8 ,,	11 ,,			

From these two sets of figures it can be seen that this root-system was in places very surface-feeding and liable to a certain amount of damage from cultivation. It should be added, however, that this tree was planted very shallow.

Example VII.

Plum ... ... Bush tree.
Plot ... ... X.
Variety ... ... Early Transparent Gage.
Stock ... ... Unknown.
Age ... ... 16 years.
Vigour ... ... Poor.
Length of root ... ... (*a*) 10ft. 7ins.
Apex of root from trunk 9ft. 6ins.

There was nothing of particular note about this tree, but some of the depth measurements given below are of interest, being comparatively close to the surface.

Root (*a*)—

Distance from point of origin at trunk.	Depth below ground level.	Distance from point of origin at trunk.	Depth below ground level.
0 in.	6 in.	26 in.	10 in.
14 ,,	8 ,,	127 ,,	5 ,,
56 ,,	13 ,,		

Remaining important roots at 3ft. 6ins. from trunk.

No.	Diameter approx.	Depth below groung level.	No.	Diameter approx-	Depth below ground level.
1	1/2 in.	11 in.	7	1/3 in.	6 in.
2	1/3 ,,	8 ,,	8	3/4 ,,	10 ,,
3	1/4 ,,	9 ,,	9	1/2 ,,	14 ,,
4	1/3 ,,	7 ,,	10	1/3 ,,	11 ,,
5	1/3 ,,	10 ,,	11	1/4 ,,	6 ,,
6	3/4 ,,	13 ,,			

Example VIII.

Plum ... ... Bush tree.
Plot ... ... X.
Variety ... ... Early Transparent Gage.
Stock ... ... Unknown.
Age ... ... 16 years.
Vigour ... ... Poor.
Length of root ... ... 7ft. 8in.
Apex of root from trunk 4ft. 8in.

This tree was a very poor specimen and is only quoted because, on uncovering the general root-system, it was found that one of the roots was striking vertically downwards, and this was considered worth investigation.

The depth measurements for this root are :—

Distance from point of origin at trunk.	Depth below ground level.	Distance from point of origin at trunk.	Depth below ground level.
0 in.	0 in.	55 in.	12 in.
17 ,,	10 ,,	64 ,,	17 ,,
37 ,,	11 ,,	92 ,,	50 ,,

In this case the root has struck vertically downwards for a matter of 28in. of its length into the stiffest of clay, which many years ago came out of a deep railway cutting near by.

The remaining data were obtained from young trees lifted in connection with other experimental work, the length of root growth only being taken.

Example IX.

Broadleaved Paradise stock.

Plot XX.

Taken from the stool in the autumn of 1920.

Longest root of last year's growth—22in.

The rows in the nursery being 3ft. apart, this root had crossed into the territory of the adjacent row before the stock had even been "worked."

Example X.

Apple ... ... Bush trees.
Plot ... ... XX.
Variety ... ... Stirling Castle.
Stock ... ... Broadleaved Paradise.
Age ... ... 4 years.
Vigour ... ... Good.
Length of root ... ... Tree (*a*) 5ft. 9in.
,, (*b*) 4ft. 9in.
,, (*c*) 4ft. 6in.

The trees were planted when two years old, the roots recorded being grown in two years.

Example XI.

Apple	Bush trees.
Plot	XX.
Variety	Allington Pippin.
Stock	Broadleaved Paradise.
Age	3 years.
Vigour	Excellent.
Length of root	Tree (*a*) 4ft. 3in.
	,, (*b*) 4ft. 8in.
	,, (*c*) 4ft. 10in.
	,, (*d*) 5ft. 3in.
	,, (*e*) 7ft. 1in.

The trees were planted when two years old, the roots recorded being grown in two years.

Considering that Stirling Castle is a very weak-growing variety and Allington Pippin only intermediate in this respect, the figures given under Nos. X and XI are rather surprising. The examples given are not isolated cases, with the possible exception of Tree (*e*), No. XI, 85in., but are merely examples to indicate the range in length of the outstanding roots.

These trees were lifted with very great trouble with practically their entire root-systems as contained in a circle with a radius of approximately 42in. from the trunk, and it was found that in all normal cases the major portion of the main roots had extended beyond the circumference of this circle. In some of the outstanding cases, as those given, the roots were followed beyond the circle. This point is of interest in connection with the practice of using weak varieties as temporary fillers between permanent trees.

Soils.

The soil analyses of the Plots so far as available are as follows :—

Geological Formation—New Red Sandstone—Keuper Marl.

	Mechanical Analysis.			
	Plot 8.	Plot 10.	Plot 14.	Plot 20.
	%	%	%	%
Surface Soil —				
Stones	Nil.	Nil.	Nil.	Nil.
Fine Gravel	0·75	1·08	0·95	1·05
Coarse Sand	7·93	8·52	6·97	7·30
Fine Sand	52·40	43·24	38·53	6·51
Silt..	10·61	13·70	12·50	9·62
Fine Silt	14·88	19·10	18·49	10·18
Clay	7·09	7·24	12·44	4·42

	Plot 8.	Plot 10.	Plot 14.	Plot 20.
	%	%	%	%
Sub Soil —				
Stones			Nil.	
Fine Gravel			1·28	
Coarse Sand			7·03	
Fine Sand			40·04	
Silt..			10·70	
Fine Silt			17 47	
Clay			15·39	
CHEMICAL ANALYSIS.				
Surface Soils—				
Moisture	1·13	1·52	3·48	
Loss on Ignition (Organic matter)	5·13	4·50	5·56	
Potash Total (K_2O).. ..	0·710	0·800	1·024	
Ditto Available (K_2O) ..	0·0143	0·0156	0·0118	
Phosphoric Acid Total (P_2O_5)	0·131	0·129	0·129	
Ditto Available (P_2O_5) ..	0·0380	0·0338	0·0385	
Calcium Carbonate ..	0·225	0·50	1·18	Nil
Lime Requirement ..	Nil	Nil	Nil	0·393
Sub Soils—				
Moisture			2·50	
Loss on Ignition (Organic matter)			3·70	
Total Potash (K_2O) ..			1·159	
Available Potash (K_2O) ..			0·0079	
Phosphoric Acid Total (P_2O_5)			0·094	
Ditto Available (P_2O_5)			0·0188	
Calcium Carbonate ..			1·31	
Lime Requirement ..			Nil	

Summary.

Although the available material was not in all cases so vigorous as might have been wished, yet even from the figures obtained, it is very evident that the roots of fruit trees extend to a greater distance from the trunk than is frequently believed to be the case. As already mentioned, this fact is very important from the point of view of planning an orchard and also applying manures. In connection with the latter, one not infrequently sees dung spread in a small circle round the trunks of trees. In actual fact this is in many cases only supplying food to ground containing for the most part the strong main roots analogous to the "scaffold" branches in the body of the tree, the major portion of the young feeding roots being much further afield.

As regards depth, the major portions of the root-systems

examined were located in the top 20in. of soil. The habit of suddenly changing in the course of growth from a more or less horizontal to a true vertical plane cannot at the moment be explained, such possible causes as lack of water, areas of soil rendered toxic by the occupation of other roots, and even obstruction by roots of neighbouring trees, not appearing to apply in all these cases. It is, however, of considerable interest, as it must be a response to a very strong stimulus. It is possible that its further occurrence in the future, which may be expected from the number of the cases met with up to the present, will throw some light on the cause.

It is hoped to add considerably to these data, working when possible with both known vegetatively propagated stocks and "free" seedling stocks. Unfortunately no material of the latter was available for inclusion in this report. It is also hoped that it will be found possible shortly, in conjunction with other institutions, to conduct a survey of fruit soils, which would include root examination in a similar way to the above. This should furnish information of much value on the relations between soil character and tree growth.

FRUIT BREEDING INVESTIGATIONS.

By G. T. Spinks.

During the year 1921 the work on fruit breeding has been continued on the lines indicated in the Report for 1920. A large number of new seedlings have been raised, the same results as before having been aimed at when making the crosses. Observations have been made on the older seedlings which are bearing fruit, and it has now been possible to discard a number of inferior seedlings, retaining for further trial only those which show signs of distinct superiority. For the next few years the work will consist to an increasing extent in recording the characters of the seedlings which have now been raised, and in selecting the best. Fewer crosses will be made: they will be chiefly duplicates of older crosses, and will be made with the object of increasing the number of individuals in a few families. It is probable that it will be better to obtain some information from the older crosses before making a large number of further new crosses. A few more details of the work in progress with the various fruits is given below.

Apples.—The following crosses were made:—

Cox's Orange Pippin × D'Arcy Spice
Ditto × Kings Acre Pippin
Ditto × Ribston Pippin
D'Arcy Spice × Cox's Orange Pippin
Ribston Pippin × Ditto
Court Pendu Plat × Royal Jubilee
Royal Jubilee × American Mother
Sweet Alford × Cox's Orange Pippin
Ditto × Bismarck
Bramley's Seedling × Sweet Alford
Lane's Prince Albert × Ditto
Wealthy × Sweet Alford.
Bismarck × Morgan Sweet
Bramley's Seedling × Ditto.
Lane's Prince Albert × Ditto.
Newton Wonder × Ditto
Stirling Castle × Ditto
Edward VII. × Wellington
Newton Wonder × Ditto
Peasgood's Nonsuch × Ditto
Wellington × Lane's Prince Albert.

It will be noticed that two varieties of cider apple, Morgan Sweet and Sweet Alford, have been crossed with several market varieties: reference to the possibilitity of useful results from such a cross was made in last year's Report. The only family of apple seedlings in which a number of individuals have fruited yet is a cross between

the two cider apples—Medaille d'Or and Kingston Black. A detailed account of the characters and chemical compositions of the fruit of these trees will shortly be published in a separate article.

Pears.—The following crosses were made :—

Catillac × Conference
Louise Bonne × Ditto
Pitmaston Duchess × Ditto
Williams' Bon Chretien × Conference
Dr. Jules Guyot × Ditto
Ditto × Pitmaston Duchess

Late blossoming was added to the list of desirable characters when making out the programme of crossing for this year.

Plums.—The following crosses were made :—

President × Czar
Pond's Seedling × Ditto
Czar selfed
River's Early × Purple Egg
Ditto × Pershore
Victoria × Ditto
Victoria × Giant Prune
Coe's Golden Drop × Ditto
Jefferson × Ditto
Giant Prune × Jefferson
Ditto selfed

The production of a good plum of the prune type, suitable for drying, is being attempted, in addition to the other projects noted last year.

Currants and Gooseberries.—With the same objects in view as last year, the following blackcurrant crosses were made in 1921 :

Baldwin × Boskoop
Ditto × French
French selfed
French × Baldwin
Boskoop × Ditto
Ditto, selfed.

From a batch of about 300 of the older blackcurrant seedlings, which had been under observation for several years, 20 have been selected as worthy of further trial, the remainder being discarded. The bushes were selected for their cropping powers and for their freedom from big bud and reversion.

Work with gooseberries this year was confined to the selfing of Careless, Keepsake, May Duke, Whinham's and Whitesmith, in the hope of obtaining a heavy cropping and very early berry for picking green.

Raspberries, etc.—No crosses were made this year, but a large number of open-pollinated seeds of the varieties—Abundance, Bath's Perfection, Baumforth's Seedling, Bountiful, Devon, Hornet, Lloyd George, Park Lane, Royal, and Superlative, were obtained. The intention is to raise several hundred plants from the seed obtained from each variety, and simply to select anything of outstanding merit which may appear, and to discard the rest. About a hundred seedlings have been raised from the seed of the selected wild blackberries, and when they commence fruiting they will be kept under observation in case any noteworthy fruit appears.

Strawberries.—The same system as last year was followed in deciding the crosses to be made, and the following were the crosses made this year :—

Bedford Champion × Maincrop
Ditto × King George V.
British Queen × La Perle
Ditto × Reward
Cropper × Vicomtesse
Fillbasket × Bedford Champion
Givon's Late × St. Antoine
King George V. × Keen's Seedling
Ditto × St. Antoine
Laxton's Latest × Earl
Laxtonian × International
Leader × St. Antoine
Louis Gauthier × Keen's Seedling
Maincrop × Bedford Champion
Madame Kooi × Dr. Hogg
President × British Queen
Queen × Dr. Hogg
Royal Sovereign × King George V.
Scarlet Queen × Ditto
Sir J. Paxton × Dr. Hogg
Ditto × St. Antoine
Vicomtesse × Cropper
Waterloo × Laxton

The crop on many of the fruiting seedlings was somewhat spoilt this year by a frost, which killed many of the earlier flowers ; but notes on the fruit of the various seedlings were made as completely as possible under the circumstances. The remainder of the plants from crosses made in 1916 and earlier years were subjected to a still further process of selection, and the few which were thought worthy of further trial are being grown in larger numbers. A preliminary selection was also made from the plants from the 1919 crosses. Plants from 1920 seed have made good crowns, but have not fruited yet. Owing to early sowing, strong young seedlings from 1921 seed were obtained in the autumn, and will be planted out in the spring.

Tomatoes.—An F_2 generation of eight families of crosses made in 1919 was grown this year. As with the other fruits, so with tomatoes, the crosses were made mainly with the object of producing some improved varieties suitable for cultivation. Several uncommon types, or varieties not grown commercially, were used as parents in some crosses, merely on the chance that something useful might result from the cross, and, therefore, some peculiar types of fruit have appeared in the F_2 generation. Probably these, and the great majority of the plants grown this year will not be grown on for another generation, as it is outside the scope of this Station to work out the genetics of the tomato. But several plants from each family were selected as being of probable value, and as many as possible of these will be carried on for at least one more generation, and crop records will be taken. Pure-breeding strains will doubtless be obtained from some of these, and may be useful either as new varieties, or, at all events, as parents, in making further crosses. In 1920 about 10 plants of the F_1 generation of each family were grown in a glasshouse. This year 60 F_2 plants of each family were grown in the greenhouse, and a similar number in the open garden. Unfortunately, it was found impossible to take complete notes on all these plants, and practically no notes were

made on the outdoor plants. But the outdoor plants were, apparently, simply a duplication of those grown inside, and nothing was noticed amongst them which had not already been seen in the indoor plants. The plants were grown in the open with the object of detecting any plant which might be specially suitable for open air culture; but nothing of this sort was found, as all the plants succeeded so well owing to the abnormally hot and dry season.

A summary of the characters of the various families is given below. The chief points noted are the size, shape, and colour of the fruit, and the size and shape of the truss. The female parent is placed first in each case.

(1) *Ailsa Craig* × *Currant* (*L. pimpinellifolium*).

Ailsa Craig.

Truss moderately compact, sometimes branched, with 5 to 8 fruits. Fruit rather flattened, 2·3 to 2·8 inches in diameter, red, moderately glossy.

Currant.

Truss very long, unbranched, with about 30 fruits. Fruit round, ·5 to ·6 inches diameter, dark red, very glossy. Plant slender, foliage pale, leaves with many small, almost entire, leaflets.

The shape of the fruit refers to the vertical section; unless otherwise stated the horizontal section is assumed to be round. The number of fruits per truss is the average number of fully developed fruits which were present.

This cross (also Crosses 3, 5, 6 and 7) was made with the object of obtaining a plant bearing long trusses of good-sized fruit, of good shape and colour.

F_1 *generation.*

Nine plants were apparently identical and the following description applies to all of them. Truss fairly long, unbranched or sometimes slightly branched, with about 12 fruits. Fruit 1·1 inches diameter, round, dark red, glossy.

F_2 *generation.*

Sixty plants. Truss long or very long, often branched, with 10 to 25 fruits. Fruit usually round, a few flattened, and one oval, ·7 to 1·4 inches in diameter, dark red, very or fairly glossy.

Descriptions and measurements of every plant were not made.

The F_1 plants were intermediate between the parents in most respects, *e.g.*, length of truss, number of fruits on the truss, size of fruit and character of foliage; but the round shape and glossiness of the fruit seem to be dominant characters. The F_2 plants were also all intermediate between the parents, though partial segrega-

tion of characters occurred. There was much variation in the size of fruits and trusses, but in no case were the extremes reached, which are found in the parents. This is, perhaps, the result to be expected when dealing with what are mainly quantitative characters. In the case of the shape and glossiness there is a more complete segregation, the round shape and very glossy skin being apparently dominant, so that the majority of the fruits are round and very glossy, though a minority are flattened and less glossy. The shape, however, is probably due to a complication of factors, as is evident from the results of other crosses. The subject of shape in tomatoes has been dealt with by Crane.* Only two plants of this F_2 family were selected for further propagation, and seeds of these were saved.

(2) *Ailsa Craig* × *Pear* (*L. pyriforme*).

Ailsa Craig.—See (1).

Pear.

Truss fairly compact, unbranched, with about seven fruits. Fruit pear-shaped, diameter 1·3 inch, length 1·9 inch, red, fairly glossy.

F_1 *generation.*

Six plants—Nos. 1, 2, 3 and 6.—Truss moderate, compact, irregular, with about nine fruits. Fruit round, diameter 1·6 inch., red. Nos. 5 and 7.—Truss rather long, irregular, with seven fruits. Fruit oval or oblong, diameter 1·8 inch, red.

F_2 *generation.*

Forty-eight plants were raised from seed from No. 1, and 10 each from Nos. 5 and 7. There was much variation in these plants, and without further and more detailed work with larger numbers it is impossible to draw conclusion about the inheritance of various characters. The extent of the variations may be judged from the following general description: Truss fairly compact or long, sometimes branched, with 5 to 15 fruits. Fruit very variable in shape, round, flattened, oval, oblong, square, and pear-shaped, diameter 1 to 2·3 inches, red, moderately glossy. This great variety of shape of the fruit was also found by Crane, when he used a long-fruited tomato, "Wonder of Italy," as a parent.

(3) *Balch's Fillbasket* × *Dobbies's Garland.*

Balch's Fillbasket.

Truss moderately compact, unbranched, with six fruits. Fruit flattened or almost round, slightly ribbed, diameter 2·5 inches, red, moderately glossy.

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* "Heredity of Types of Inflorescense and Fruits in Tomato."—*Journ. Genetics*, Vol. V., 1915, p. 1.

Dobbie's Garland.

Truss long, unbranched, with about 25 fruits. Fruit round, diameter ·8 to 1 inch, dark red, very glossy. (Very similar to the "Currant," but the fruit is distinctly larger and there are not quite so many fruits on the truss.)

F_1 *generation.*

Truss fairly long and lax, often branched, with 12 to 20 fruits. Fruit round, diameter 1·2 inch, dark red, glossy.

F_2 *generation.*

Truss long or very long, often with 2 or 4 branches. Number of fruits varies between 8 and 80, the latter number occurring on a long 4 branched truss. Fruit round or rather flattened, diameter ·9 to 1·8 inch, red, moderately or very glossy.

The inheritance of size, colour and shape is on the whole similar to that found in cross (1), the F_1 plants being intermediate and all alike, while the F_2 plants are also all intermediate, but have a fairly wide range of variation. The characters of Dobbie's Garland seem to be more or less dominant. Of the 60 F_2 plants 15 were classified as having fairly large fruit, and 45 as small or medium fruited. In addition to the typical round or slightly flattened fruit, two plants were found bearing distinctly oval fruits, and several others with slightly oval fruit. It is noticeable that the F_2 plants included some with trusses much longer, and bearing many more fruits than those of either of the parents. Three plants with trusses bearing 8 to 12 fruits each, about 1·8 inch in diameter, were selected for further propagation.

(4) *Balch's Fillbasket* × *Yellow Peach.*

Balch's Fillbasket.—See (3).

Yellow Peach.

Truss moderately compact, unbranched, with 5 to 7 fruits. Fruit round, slightly flattened, diameter 1·9 inch, pale yellow, dull, pubescent.

F_1 *generation.*

Truss fairly compact, rather irregular, with 7 fruits. Fruit slightly flattened and slightly ribbed, diameter 2·2 inch, rather pale red, dull.

F_2 *generation.*

Truss compact to moderately long, with 5 to 8 fruits. Fruit round or flattened, diameter 1·8 to 2·5 inch, red, pink or yellow, dull or glossy.

Detailed notes of each plant were not taken in this case, but on the whole the inheritance of characters seemed to be the same as in (8) below. Only one plant was selected for possible further trial.

(5) *Holmes's Supreme* × *Currant.*

Holmes's Supreme.

Truss moderately compact, with about 4 (3 to 6) fruits. Fruit rather flattened, slightly ribbed, diameter 2·3 inch, dark red, fairly glossy.

Currant.—See (1).

F_1 *generation.*

Truss moderately compact, seldom branched, with 12 to 20 fruits. Fruit round, diameter 1 inch, red, fairly glossy; 12 plants all alike.

F_2 *generation.*

Truss moderately or very long, with 12 to 25 fruits. Fruits round, diameter ·7 to 1·4 inch, red, fairly glossy. Here again notes were not made on all individuals, but the family as a whole was very similar to (1) and (6). Two plants were selected for propagation.

(6) *Kondine Red* × *Currant.*

Kondine Red.

Truss fairly compact, with 5 fruits. Fruit slightly flattened, diameter 2·3 inch, red, moderately glossy.

Currant.—See (1).

F_1 *generation.*

Truss long, seldom branched, with 11 to 14 fruits. Fruit round, diameter 1 inch., red, very glossy. The 12 F_1 plants were all alike and in most respects were intermediate between the parents, though the round shape of the fruit seems to be fairly dominant.

F_2 *generation.*

Truss compact, moderate or long, usually unbranched, with 6 to 20 fruits. Fruit round or flattened, diameter ·7 to 1·4 inch, red, glossy.

In the F_2 generation there was much variation amongst the 60 plants which were observed, though, as in (1), the limits of the original parents were never reached. As regards the type of truss, approximately equal numbers were noted as compact, moderate, and long, though no actual measurements were made. The majority of the fruits were about the same size as those on the F_1 plants, and three quarters of the total numbers were between ·8 and 1·2 inch in diameter. Seven plants bore fruit over 1·2 inch in diameter, but the largest fruits were 1·4 inch, no fruit approaching anywhere near the size of that of Kondine Red. The fruit of eight plants had a diameter of less than ·8 inch, but in only one case was the fruit as small as that of the Currant. The size of the fruit

in all the plants of the F_2 generation is, therefore, seen to be much influenced by the Currant parent. This is also the case with the shape of the fruit, as on 28 plants it was classified as round, on 23 as slightly flattened, and on 6 as distinctly flattened. All the fruits were described as red and glossy, but no further details were noted, except that in one case a fruit was described as dark red. Six plants occurred which were distinctly dwarfed and slender in growth, and resembled the "Currant" parent in their foliage and fruit, though only one of them bore fruit quite as small as the "Currant" and none of them carried so many fruits on each truss.

(7) *Kondine Red* × *Dobbie's Garland.*

Kondine Red.—See (6).

Dobbie's Garland.—See (3).

F_1 *generation.*

Truss long, sometimes branched, with 10 to 12 fruits. Fruit slightly flattened, diameter 1·4 inch, red, glossy. 9 plants.

F_2 *generation.*

Truss moderate to very long, sometimes branched, with 6 to 40 fruits. Fruit round, flat or intermediate, diameter ·7 to 1·9 inch, red, glossy.

On the whole the products of this cross resemble those of cross (3). The F_1 plants are again intermediate in almost every respect. The F_2 plants are also usually intermediate, though a few are more extreme than the parents. On one plant branched trusses carrying up to 40 fruits occurred. Most of the fruits were between 1·2 and 1·7 inch in diameter, though a few were smaller or larger than this, 9 of them being as small as the fruit of Dobbie's Garland, though none were as large as Kondine Red. The fruit of 15 plants was round, that of 5 was much flattened, and that of the remainder of an intermediate shape. Most of the fruits were regular in shape, but 4 of the more or less flattened ones were ribbed. All the fruit was red and glossy, two plants being noted as bearing very bright red fruits.

Two plants were notable for the extraordinary growth in length which they made: they were stopped, like all the other plants, above the fourth truss of fruit, and were then two or three feet higher than the rest of the plants. These plants bore extremely long fruit trusses, the longest being 5ft. 6in. long; but the trusses usually bore about 20 small fruits, as the flowers were very far apart and many of them failed to set fruit; the flower stalks were also much longer than usual.

This cross was, perhaps, the most promising of any as regards the production of useful types of plants, and seed from five of these was saved for further trial.

(8) *Kondine Red* × *Yellow Peach.*

Kondine Red.—See (6).

Yellow Peach.—See (4).

F_1 *generation.*

Truss moderately long and irregular, with 5 to 7 fruits. Fruit rather flattened and slightly ribbed, diameter 2·2 inch, pale red, dull.

F_2 *generation.*

Truss moderate in length, sometimes branched, with 4 to 10 fruits. Fruit either flat or somewhat flattened, often ribbed, diameter 1·5 to 2·8 inch, red, pink or yellow, moderately glossy or dull.

The chief point of interest in this cross is the inheritance of colour. In the F_2 generation there were counted 25 rather pale reds, 12 pinks, 9 dark yellows, and 4 light yellows. Reds have red flesh and dark yellow skin, pinks have red flesh, but a colourless skin, dark yellows have yellow flesh and yellow skin, and light yellows have yellow flesh but colourless skin. It seems likely that with a larger number of plants a 9 : 3 : 3 : 1 : ratio between the different colours would have been obtained, red flesh being dominant to yellow, and yellow skin dominant to colourless, but the flesh and skin colours being independent of each other. This agrees with the observations of other breeders of tomatoes. The dull surface of the Yellow Peach appears to be at all events partially dominant. Another point of interest which appeared was the tendency of much of the fruit on the outdoor plants of this cross to become soft long before it was ripe—a character to be avoided, inherited from the Yellow Peach parent. Actual figures of the proportion of fruits which showed this character are not available, but it was probably a large majority of the F_2 fruits. Three plants were selected for a possible further trial.

No information with regard to the inheritance of susceptibility or resistance to disease has been obtained from any of the crosses, as the whole of the plants for the last two years have been remarkably free from *Cladosporium* and other diseases.

POT EXPERIMENTS ON THE MANURING OF FRUIT CROPS.

By T. Wallace.

A large number of field experiments on the manuring of fruit crops have been carried out in America, but very few have been carried out in this country. Of these latter experiments, those of Pickering at Woburn, and of Dyer and Shrivell in Kent, constitute the most complete series.

All workers on this subject have recognised that the problem is vastly different from and much more complex than the problem of the manuring of farm crops, and as there is already a considerable literature on the possible effects which manures may produce on fruit trees, it is not proposed to add to this in this paper.

The point which is brought out most strongly in comparing the results obtained in previous experiments is that the results show no agreement among themselves, especially in the experiments on the manuring of apple trees.

The results obtained in America on apple trees may be summarised as follows :—

In cultivated orchards, sometimes no result whatever has been produced on the trees as the result of applying fertilisers ; sometimes an increased growth of the trees has resulted without any increase in the yield of fruit being obtained, and occasionally the quantity of fruit obtained has been increased to such an extent as to make the application of manures a paying proposition. In grass orchards remarkable increases in crops have been obtained in some cases by the application of quick-acting nitrogenous manures, such as nitrate of soda.

In this country, the results obtained at the various centres on the various fruit crops show little agreement. Pickering obtained entirely contradictory results on apple trees on the two types of soil at Woburn. On one soil type he found that the application of manures produced no effect on the trees, whilst on the second type the trees appeared to re-act normally to the manures.

With bush fruits—gooseberries and currants—the crops were

greatly increased by applications of dung on both types of soil, but differing results were obtained from the use of artificial manures on the two soils.

Only small crop increases were obtained by the application of manures to strawberries, but it was thought that the soil was unsuitable for this crop.

Dyer and Shrivell obtained positive effects from various schemes of manuring on different types of fruit crops and ventured to make tentative recommendations for the manuring of some of these.

In view of the facts that the great majority of the leading fruit growers of this country spend large sums of money on manures annually, and that the results of previous experiments on the manuring of fruit crops have been so contradictory and inconclusive, it appeared desirable to carry out experiments at this Station to attempt to determine the effects of various manurial treatments on the various fruit crops.

It was felt that before proceeding with field experiments, it was desirable to carry out experiments more of the laboratory type in order that the various effects produced could be studied in greater detail, and in order that the trees, bushes or plants under experiment could be kept more easily under controlled conditions and certain factors entering into field experiments eliminated.

General Plan of Experiment.

With this idea in mind, it was decided to attempt to carry out very simple series of manurial experiments on the following lines. Apple trees, gooseberry and currant bushes, and strawberry plants were to be grown in silver sand contained in unglazed pots, which had been waxed previously to render them more impervious to water, and in each case the effects of feeding the trees, bushes or plants in question with various nutrient solutions were to be studied. In each case the scheme of feeding was to be as follows:—

Series A.—Fed with a complete nutrient solution.
„ B.— „ „ „ „ „ „ but an extra amount of Sodium Sulphate to be given.
„ C.—Nitrogen to be omitted from the complete nutrient solution.
„ D.—Potash „ „ „ „ „ „ „
„ E.—Phosphoric Acid „ „ „ „ „ „ „
„ F.—Calcium to be omitted „ „ „ „ „ „
„ G.—Magnesium „ „ „ „ „ „
„ H.—Rain Water only to be given.

The composition of the complete nutrient solution which was to be used is given below, and the other solutions were to be formed from this by substituting soda for any base to be omitted, and the sulphate radical where an acid radical was to be omitted. Series B was to be included as the scheme above entailed the introduction of amounts of soda and sulphate radicals into the various

solutions in excess of the quantity present in the complete nutrient solution. Rain water was to be used in making up all the nutrient solutions as it was felt that very large quantities of water would be necessary, to carry out this work.

Composition of the Complete Nutrient Solution.

Sodium Nitrate	5·0 gms.
Potassium Nitrate..	2·0 ,,
Potassium Di-hydrogen Phosphate	1·0 ,,
Calcium Sulphate	1·0 ,,
Magnesium Sulphate	1·0 ,,
Sodium Chloride	1·0 ,,
Ferric Chloride	0·4 ,,
Rain Water	To 1 litre.

1 litre of solution to be diluted with 9 litres of rain water previous to application.

Experimental.—Experiments on these lines were commenced on apple trees and strawberry plants during the winter 1920–1921, in order to test the method of experiment and to gain some preliminary knowledge as to how the trees and plants were likely to re-act under the treatments.

As the result of one season's work, many interesting points have been brought out, and it has been decided to extend the work to gooseberries and black currants during 1922. Fresh series on apples and strawberries are also to be commenced then.

Although the experiments on the apples and strawberries have only been in progress over one season, certain results, which must be regarded as purely qualitative at this point, have been obtained, which it appears desirable to put on record even at this early stage of the investigation. The results recorded are not to be regarded as being of a final character, and it is probable that as the experiments proceed over the successive seasons many of the differences observed at this stage will be modified, whilst it is obvious that in the case of apple trees the results of the first season must be influenced to a certain extent by the reserves of food material previously stored up in the tree. It is intended to publish further progress reports on the experiments during the next few seasons, and attention will be drawn in these to any marked changes which the trees and plants undergo as the experiment progresses.

A detailed account of the experimental work carried out and of the observations made during the season of 1921 is given below.

Weather during Season 1921.—The season was one of the hottest and driest on record. Temperatures between 80°F.–89°F. in the shade were quite frequent, especially during July, in which month 10 readings of over 80°F. were recorded. Only 6.68 inches of rain fell from March 1st–July 31st. The rainfall from this latter date to the end of the growing season was light. The first late season frost was recorded on October 24th.

Experiment on Apple Trees.

Forty trees—variety Cox's Orange Pippin, said to be on broad-leaved Paradise stock—are being used in this experiment. They were divided into eight series, each of which consisted of five trees. The series were lettered from A to H, and the trees of these series were fed with the respective nutrient solutions as described for the series on page 44.

The pots used in this experiment are 10in. plant pots. Previous to their being used, they were dipped in molten paraffin wax and the holes at the bottoms were covered with fine copper gauze to prevent the sand from running through. Ten kilograms of dry silver sand are used in each pot.

The method of feeding the trees throughout the season has been to maintain the moisture contents of the sand between 16%–20% of the weight of the sand in the pots by means of the respective nutrient solutions.

The sand in each pot has been leached through fortnightly with rain water to prevent the accumulation of salts or toxins in it.

The tops of the pots are covered with pieces of tarpaulin to protect the contents from rain, etc., and to prevent excessive surface evaporation.

Planting.—All the trees were planted on February 25th, 1921. Previous to planting, the roots of all the trees were treated in the Stringfellow method, *i.e.*, all laterals were removed and only the "carrot stump" left. All the trees received a normal winter pruning after planting.

Position of trees.—From the time of planting until 1st October, 1921, the trees stood in the open. They were prevented from being blown about by the wind by tying each to a strand of wire stretched between wooden uprights. In order to protect the pots from frost damage they were removed on October 1st to a glass-roofed shed with open sides.

Observations made during the season.—Observations were made on the following points :—

(*a*) Times of opening of buds.
(*b*) Types of foliage produced.
(*c*) Times of the falling of the leaves.
(*d*) Lengths and types of shoot growth made.
(*e*) Types of root systems made.

Note.—All blossom produced was removed at an early stage.

(*a*) *Times of opening of buds.*—The only point of note was that the buds of one tree of each of the series, with the exception of Series F, were later than the buds of the remainder

of the trees in bursting into leaf. The leaves of these trees up to the middle of July were much smaller than those of the other trees, and it appeared as though the trees in question had experienced some difficulty in becoming established in the sand. On examining the root systems of the trees on December 10th, 1921, it was found that the roots of these latter trees were of the free stock type, whilst those of all the others were of the Paradise stock type.

(*b*) *Types of foliage produced.*—Some very interesting observations have been made on the types of foliage carried by the trees of the different series throughout the season and it was obvious from these observations that the different manurial treatments were producing effects within the trees from quite an early date in the season. By the end of June, there were marked differences to be seen in the characters of the leaves. A detailed examination of the foliage was made on July 6th, and an account of the observations made on this occasion is given below.

Note.—In the detailed descriptions which follow on the types of foliage, types of root systems, etc., the trees are given definite serial numbers, *e.g.*, Series A., 1, 2, 3, 4, 5. Series B., 1, 2, 3, 4, 5, etc.

Series A.

Nos. 1, 4, showed no leaf scorch.

No. 2.—A small amount of leaf scorch was present at the tips of the leaves.

No. 3.—Showed a medium amount of leaf scorch at the tips and along the margins of the leaves.

No. 5.—The leaves were badly affected with marginal leaf scorch.

Some of the leaves of Nos. 2, 3, 4, were turning yellow. The leaves of No. 1 were still very small. Throughout this series, the leaves were generally well developed in size and were dark green in colour.

Series B.

No. 1 showed no leaf scorch, and the leaves were small, as in A 1.

Nos. 2, 3, 4.—There was a fair amount of tip scorch present.

No. 5.—The leaves were affected with leaf scorch to a similar extent, as in A 5.

The leaves of the trees in this series were very similar to those of the trees in Series A in colour, size, and the amount of leaf scorch present. Some of the leaves were turning yellow.

Series C.

There was no leaf scorch present on any of the trees.

The leaves of the trees of this series were similar in size to those in Series A, but were lighter green in colour.

Series D.

No. 1 showed no leaf scorch. The leaves were small, as in A 1.

Nos. 2, 3, 4, 5.—The leaves of all these trees were badly affected with leaf scorch.

The leaves of the trees of this series, previous to their becoming badly scorched, were similar in size and colour to those of the trees in Series A, and had shown no signs of being in any way abnormal.

Series E.

No. 1.—There was no leaf scorch present. The leaves were small as in A.1.

Nos. 2, 4, 5.—There was no leaf scorch showing.

No. 3.—The leaves were slightly affected with leaf scorch at the tips.

The leaves of the trees in this series appeared to be somewhat smaller than those of Series A, and were slightly lighter green in colour.

Some of the leaves of Nos. 2, 3, 4, 5, were turning slightly yellow.

Series F.

Nos. 2, 3, 4.—There was no leaf scorch present on these trees.

Nos. 1, 5.—The leaves showed a little leaf scorch at the tips.

The leaves of the trees of this series were generally large and well developed, and their colour was practically normal. Nos. 1, 5, showed considerable yellowing of the leaves.

Series G.

A small amount of leaf scorch, mostly at the tips of the leaves, was showing on all the trees of this series.

The leaves of these trees were identical in appearance to those of Series A.

The leaves of No. 1 were smaller than those of the other trees of this series. Nos. 1, 2, 3, showed slight yellowing of the leaves.

Series H.

The leaves of the trees of this series were similar to those of Series C, being of normal size, light green in colour and showing no leaf scorch.

Summary of observations.

1.—The leaves in Series E appeared to be slightly below the size of those in the other series.

2.—The leaves in Series C, E, H, were lighter in colour than those of Series A.

3.—Leaf scorch was present to the greatest extent in Series D.

The amounts present in Series A, B, G, were approximately equal. In Series E, F, the amounts of leaf scorch were less than in Series A. There was no leaf scorch present in Series C, H.

Thus it will be seen that in this experiment, when trees were grown in sand and fed with a complete nutrient solution, they developed a certain amount of leaf scorch. The amount of leaf scorch was increased by the omission of potash from the nutrient solution and decreased by the omission of calcium and phosphoric acid. Leaf scorch was entirely absent when nitrogen was omitted and when the trees were given rain water only.

(*c*) *Times of the falling of the leaves.*

On the occasions on which observations were made on the times of the falling of the leaves in the different series, observations were also made on the character of the leaves at that time of the year, and on the colour changes which were developed during the period of falling, etc., and it was observed that certain differences were apparent at this time of the season which had not been evident at the time of making the observations recorded on July 6th.

An account of the observations made on the individual trees on September 24th, and of some summarised results of observations made at later dates, is given below.

Observations made on September 24th.

Series A.

Nos. 1, 2, 3, 4.—There was no leaf scorch present on these trees.

No. 5.—A small amount of leaf scorch was present.

The trees of this series were still in full leaf. The leaves were of a normal green colour and showed no signs of falling.

Series B.

No. 1.—There was no leaf scorch present.

Nos. 2, 3, 4, 5.—A small amount of leaf scorch, mostly at the tips of the leaves, was showing on these trees.

The leaves were similar in size and colour, etc., to those of Series A.

Series C.

There was no leaf scorch present on any of the trees.

Nos. 3, 5, were completely defoliated.

Nos. 2, 4, were partly defoliated. The leaves remaining were pale green in colour.

No. 1.—This tree was in full leaf and the leaves were of normal size and colour.

Series D.

No. 1.—The leaves showed slight scorch, mostly at the tips.

Nos. 2, 3, 4, 5.—The leaves of all these trees were badly affected with leaf scorch.

The colour of the leaves where scorch was not present was similar to the colour of the leaves in Series A. Some leaves had fallen.

Series E.

Nos. 1, 2, 4, 5.—There was no leaf scorch present on these trees.

No. 3.—The leaves showed slight leaf scorch, mostly at their tips.

The leaves in this series were smaller than those in Series A, and were still green.

Some leaves had fallen.

Series F.

Nos. 2, 4.—There was no leaf scorch on these trees.

Nos. 1, 3, 5.—The leaves were showing a small amount of leaf scorch.

The leaves on all the trees were large and well developed.

Some leaves on No. 2 were turning yellow.

Series G.

Nos. 1, 2, 3.—The leaves were slightly affected with leaf scorch.

Nos. 4, 5.—The leaves of these trees were severely affected with leaf scorch and were similar in appearance to those of the badly affected trees of Series D.

The leaves of all the trees of this series had commenced to fall.

Nos. 4, 5, had lost considerable proportions of their foliage, and the leaves remaining were in very poor condition.

By October 10th, the leaves of all the trees of this series were very badly affected with leaf scorch.

Series H.

There was no leaf scorch present on any of the trees.

No. 1 was still in full leaf, and the leaves were green.

Nos. 2, 3, 4, 5.—These trees were partly defoliated, and the leaves remaining showed a considerable amount of yellowing.

Summary of observations.

(1) The trees of Series D again showed the largest amount of leaf scorch. Those in Series G had developed leaf scorch to a great extent since July 6th, and they now showed leaf scorch second in amount to those of Series D. The trees in Series A, B, F, were affected with leaf scorch to similar extents. The amount of scorch present on the trees in Series B was slightly greater than on those in Series F, and slightly greater on the trees in Series F than on those in Series A.

The amount of leaf scorch in Series E was very small, and was less than in Series A.

As on July 6th there was no leaf scorch present on the trees of Series C, H.

(2) The trees of Series A, B, F, were still in full leaf. A small proportion of the leaves in Series D, E had fallen.

Some of the trees in Series G and H had lost a considerable proportion of their leaves. Two trees in Series C were completely defoliated, and two other trees were partly defoliated.

Observations made on October 21st.

Series A.—One tree was defoliated and two trees still retained practically all their leaves.

Series B.—One tree was defoliated, and the foliage remaining on the other trees was very sparse.

Series C.—Three trees were defoliated. The foliage on the two other trees was very thin.

Series D.—There was no tree completely defoliated. Four trees were carrying only a small amount of poor scorched leaves, and one had practically a full amount of healthy foliage.

Series E.—One tree was carrying a full amount of foliage. The amounts of foliage on the other trees were small.

Series F.—All trees had a fair amount of foliage on them. There was more foliage retained in this series than in any other.

Series G.—All the trees were practically defoliated, and the leaves remaining were poor and scorched.

Series H.—Two trees were defoliated, and two practically defoliated. One tree was carrying practically a full amount of healthy foliage.

Order of series of retention of leaves.—F, A, E, B, D, G, H, C.

Observations made on November 5th.

(1) Order of series of retention of leaves—F, A, B, E, D, G and H, C.

(2) Colour changes of the leaves were most strongly developed in Series C, F, H, E.

(3) The trees on the free stock types, previously referred to, were retaining their leaves best in all cases.

Observations made on November 19th.

Order of series of retention of leaves—F, A and B, E, D, G, C, H.

(1) The trees in Series H were all defoliated.

(2) With the exception of the trees in Series F, all the trees of the other series were either almost or completely defoliated.

Observations made on December 10th.

All the trees were defoliated.

(*d*) *Lengths and types of shoot growth made.*

Measurements of the lengths of shoot growth made by the trees during the season were taken on November 19th. On this occasion observations were also made on the characters of the shoots in each series. These results will be affected to a certain extent by the pruning which the trees were given after planting, but the differences in some cases are so great that there is no doubt that the amounts and character of shoot growth made have been determined to a great extent by the manurial treatments given. The results tabulated below will serve to give some idea of the orders of shoot growth made in the different series.

Series.	Average per tree total shoot growth. m.ms.	Length of longest shoot per series. m.ms.	Observations on the type of shoot growth (i.e. thickness) made.
F.	1120·8	226	Shoots of medium thickness.
A.	939·2	256	,, ,, normal ,,
G.	924·6	177	,, ,, medium ,,
B.	799·6	211	,, ,, ,, ,,
E.	764·2	161	,, below medium ,,
H.	629·6	134	,, very thin
D.	608·2	139	,, below medium ,,
C.	560·2	133	,, very thin.

NOTE—The term medium denotes midway between normal and very thin.

Without wishing to lay any great stress on these results, it would appear that the omission of calcium may tend to increase the length of shoot growth, as it may also tend to prolong the growing period, as shown by the observations on the retention of the leaves, whilst the omission of potash or nitrogen or the withholding of food altogether would appear to limit the amount of shoot growth.

(*e*) *Types of root systems formed.*

The root systems of the trees were examined on December 10th, and the observations made are recorded in detail below.

Series A.

No. 1.—The root system of this tree differed in type from the remainder of the trees of this series. It is probably of the free stock type, whilst the others are of the Paradise stock type.

The root system of No. 1 was much smaller than those of the others.

Nos. 2, 3, 5.—The root systems were well developed and showed fair amounts of recent growth.

No. 4.—The root system of this tree was similar to those of Nos. 2, 3, 5, but not so well developed.

The root fibres in all cases were coarse. The roots in this series looked quite healthy.

Series B.

No. 1.—The root system was similar to that of A 1.

Nos. 2, 3, 4, 5.—These trees all had root systems similar in size, type of fibre, healthy appearance, and amount of recent growth to A 2, 3, 5.

Series C.

No. 1.—The root system was similar to that of A 1.

Nos. 2, 3, 4, 5.—The root systems were similar in size to those of A 2, etc. They differed from these in the fact that the root fibre was finer and there was practically no recent growth to be seen.

Series D.

No. 1.—The root system was similar to A 1.

Nos. 2, 3, 4, 5.—The root systems were all smaller in amount than the root systems of C 2, 3, 4, 5. The root fibre was similar in appearance to that of Series A, being coarser than in Series C. The roots showed more recent growth than those of this latter series.

Series E.

No. 1.—The root system was similar to A 1.

Nos. 2, 3, 4, 5.—The root systems were similar in size to A 3. The fibre was coarse and the roots appeared to be healthier in colour than in any other series. The amount of recent growth was greater than in Series A.

Series F.

The amounts of root formed by the trees of this series were less than in Series A, and the root fibre was finer than in this latter series. The amount of recent growth made was greater in this series than in any other.

Series G.

No. 4.—The root system was similar to A 1.

Nos. 1, 2, 3.—The roots of these were similar in size and character of fibre to those of Series A. There was a fair amount of recent growth to be seen.

No. 5.—The root stock appeared to be weaker than in Nos. 1, 2, 3, but was similar in type to these.

The roots of this series were inclined to be black, and it is probable that they were to a certain extent unhealthy.

Series H.

No. 1.—The root system was similar to A 1.

Nos. 2, 3, 4, 5.—The root systems of these trees were similar in amount and type of fibre to those of Series C.

The amount of recent growth was greater than in Series C, whilst the colour of the roots was slightly darker in this latter series.

Summary of observations on the root system.

Series D.—The amounts of root formed during the season by the trees in this series were smaller than in any other series. The root fibre was of a similar degree of coarseness to that in Series A.

The amount of recent growth made was greater than in Series C, H.

Series C, H.—The root systems in these two series were similar in amount and type of fibre. The amounts in each series were almost equal to those of the trees in Series A., but the fibre was much finer.

In Series C practically no recent growth had been made, whilst in Series H there had been a certain amount of recent growth made.

Series F.—The amounts of root made by the trees were less than those made by the trees in Series A. The type of root fibre was similar to that of the trees in Series C, H. The amount of recent growth made was greater than in any other series.

Series G, E, A, B.—The amounts of root and the types of root fibre made by the trees in these series were similar.

In Series E, the roots looked healthier than in any other series, and the amount of recent growth made was second to that made in Series F.

The roots in Series A, B appeared to be practically identical in all respects.

The roots in Series G were blacker than those of the other series, which probably indicated unhealthy conditions.

NOTE.—Trees A 1, B 1, C 1, D 1, G 4, H 1, appeared to be on root stocks of the free stock type, whilst all the remaining trees were on stocks of the Paradise stock type.

EXPERIMENT ON STRAWBERRY PLANTS.

The variety used in this experiment is Royal Sovereign.

Eighty plants—10 per series—are being used in the series A—H, and two further series, X and Y,—six plants per series—have been commenced to test the effect of leaching the sand in the pots fortnightly against non-leaching of the sand.

In general, the details of the procedure described in the Experiment on Apple Trees have been followed in this experiment. The only points of difference are as under :—

The pots used are 6in. plant pots.

The tops of the pots are covered with waxed cardboard discs, each having a hole through the centre large enough to allow the roots of the plants to be passed through.

The weight of dry sand per pot used is 2.5 kilograms.

Planting.—All the plants were planted in the pots on December 11th, 1920.

Position of plants.—From December 11th, 1920, to March 24th, 1921, the plants were kept in the greenhouse, and on March 24th they were removed to a shelter which has three open sides and a glass roof. In this latter position the plants were practically under open air conditions, but were protected against rain. The plants were moved back into the greenhouse on October 20th, where it is proposed to keep them until next spring.

Pest attacks.—Just prior to the removal of the plants from the greenhouse to the shelter on March 24th, they were attacked in a mild degree by aphides, and these persisted on the plants during

the summer. No spraying against pests was carried out, nor is it intended to do so in future seasons, as it is desired to make observations on the relation between the liability to injury from pest attacks and the various manurial treatments.

Observations made during the season.

Observations were made on the following points :—

(*a*) Growth of plants and types of foliage.

(*b*) Changes taking place on the foliage in autumn.

(*c*) Crop weights.

NOTE.—The plants have been allowed to fruit freely, but all runner formation has been checked.

(*a*) and (*b*). These are considered together below.

From the date of planting until the end of September, 1921, there was very little difference to be seen among the plants of the different series (excluding the plants of Series X and Y, which are not directly comparable, as these plants were smaller than those of the other series before the treatments were started) with the exception of the plants of Series C and H, in which series the plants had made no apparent growth throughout the season, though, perhaps, the plants of Series A were always a little larger than those of the other series. The plants of all the series, other than C and H, were of a good healthy green colour.

From the latter half of September, differences began to show up between the plants of the different series, and by November 19th considerable differences were apparent.

Details of observations made on various dates from September 24th onward are given below.

Observations made on September 24th.

All the plants were still green, those of Series C and H being slightly paler green in colour than those of the other series. The order of the series as regards size was—A, B, D, F and G, E, H, C. The plants in Series A were only slightly ahead of those of Series B in general appearance. Series B plants were slightly ahead of those of Series D, F, G. Series E plants were decidedly behind those of Series D, F, G. Series H and C plants were almost identical in appearance, and were much behind those of the other series.

Plants of Series X and Y.—The plants of both series were a good colour. Those of Series X (unleached) were between those of Series E and H in size, and those of Series Y (leached) were larger than those of Series E.

Observations made on November 19th, 1921.

The order of the series as regards size was—A, B, D and F, G, E, C, H.

Series A.—The plants looked healthy, the leaves being green and well developed.

Series B.—The plants looked healthy, but the leaves were generally smaller than in Series A, and some were lighter green in colour, and looked as though they were beginning to change colour.

Series C.—The plants were very poor and much of the foliage had turned yellow or red.

Series D.—The plants were very similar to those of Series B, though the leaves, on the whole, were slightly smaller than those of this latter series. All the leaves were still green.

Series E.—The plants of this series were much behind those of Series D, F and G. They were much smaller, and looked unhealthy. The leaves showed much yellowing.

Series F.—The plants were identical in appearance to those of Series D.

Series G.—The plants were similar in appearance to those of Series F, but were slightly smaller. The leaves had shorter stalks, and were smaller than in F. They were beginning to change in colour to pale green and yellow.

Series H.—The plants were slightly behind those of Series C in appearance. Most of the leaves were red or yellow in colour, and very few were green. On the whole the plants showed more reddening of the leaves than in Series C, where the leaves had changed more to yellow than red.

Series X.—The plants were slightly larger than in Series H, the leaves also being larger. They showed no tendency to turn yellow, but many showed a brown marginal scorch.

Series Y.—The plants were much better than in Series X. Some of the leaves were turning yellow, and there was no brown marginal scorch, as in X.

Observations made between November 19th—December 13th, 1921.

Numerous observations on the plants were made during this period. The order of the series, as regards size of plants, did not change during this time, but the leaves in all the series had developed much change in colour and some of the foliage of all the plants

had turned brown and dried out. The plants in Series C, H and X, were all in very poor condition, and they will probably have some difficulty in commencing growth next spring. With regard to the colour changes of the leaves, which took place during this period, the leaves in all the series, with the exception of Series C, H and X, had changed to yellow or reddish yellow. In Series C and H the change had been more to red than yellow, and more so in Series H than in Series C. In Series X the leaves had developed a brown marginal scorch, which had spread over the whole areas of the leaves, and had not turned either yellow or red.

Summary of Observations on the Growth of the Plants.

(1) The plants fed with the complete nutrient solution in Series A have made good growth.

(2) Nitrogen and phosphoric acid appear to be very essential to the growth of strawberry plants.

(3) The omission of potash, calcium and magnesium respectively has not restricted the growth of the plants to a great extent during one season.

(4) As the result of non-leaching of the contents of pots receiving a complete nutrient solution, the plants developed a brown marginal scorch at the end of the season. Two plants of this series have died during the season.

(*e*) *Crop weights.*

The crop weights of the individual plants have been recorded during the season, but it is felt that no useful purpose would be served in publishing these at this stage of the work.

THE ASSOCIATION OF BLACK CURRANT MITE *(Eriophyes ribis)* WITH REVERSION DISEASE.

By A. H. Lees.

For some years certain growers of black currants familiar with both diseases have been of the opinion that there is a close association beween the two. Not every grower holds this opinion, but the fact that some do, and that field experience supports the idea, made it advisable to collect statistical information at the Research Station. In order to do so a small plantation of about 250 bushes was selected for trial. The plantation was not ideal for this purpose, as the bushes were cuttings from seedlings and so might be excepted to vary greatly in resistance and general behaviour. No other plantation was, however, available. For two years each bush has been marked twice, once in winter for amount of Big Bud and once in summer, about June, for amount of Reversion. The amounts of Big Bud infection were arranged in six classes 0—5, and the Reversion into three—normal, partly reverted, and reverted. The symbols used for these classes are N, F R (fractionally reverted) and R. A partly reverted bush was one which showed part of the bush only reverted, or the whole bush partly reverted, according to the leaf vein method.

By this means the behaviour of every bush over the two years was noted. For instance a bush having marking N I R O, would mean that in the first summer it was normal, in the second revert, in the first winter it had a very few big buds in the second, none. Similarly F R I R 3 would mean partly revert in the first summer and revert in the second, Class 1 Big Bud in the first winter and Class 3 in the second.

Table 1 shows the association of the various classes of Big Bud, with the amounts of Reversion for both years. The figures are expressed as percentage of the total class figures (0—4, class 5 being absent), that occur in the three classes of Reversion. Thus in Class 0, first year, 66% were normal, 18% fractionally revert and 15% fully revert.

TABLE I.

1st Year—Percentages.

	Class 0.	Class 1.	Class 2.	Class 3.	Class 4.
N ..	66	21	4	0	0
F R ..	18	8	5	0	0
R ..	15	71	90	100	100

2nd Year—Percentages.

	Class 0.	Class 1.	Class 2.	Class 3.	Class 4.
N ..	81	30	0	0	0
F R ..	10	28	16	10	0
R ..	9	42	84	90	100

The points that this table bring out are as follows :—

(1) In each year a high percentage of Class 0 are normal.

(2) In each year a high percentage of Classes 2—4 are revert.

(3) The fractionally revert occur mostly in Classes 0—2 in both years.

(4) In the first year none of Class 3 or 4, and in the second year none of Class 2, 3 or 4 were normal.

It is approximately true to say that as soon as a bush reaches Class 2 of Big Bud infecton it ceases to be normal.

Table 2 gives the number of bushes occurring in all the possible combinations. All classes of Big Bud infection are denoted by the symbol 1, its absence by 0.

TABLE II.

NONO	62	NINO	9	RONO	2	RINO	1
NONI	14	NINI	6	FRONO	14	FRINO	4
NORO	3	NIRO	0	RONI	0	RINI	1
NOFRO	5	NIFRO	0	FRONI	3	FRINI	2
NORI	1	NIRI	0	RORO	3	RIRO	2
NOFRI	3	NIFRI	4	FRORO	1	FRIRO	0
				ROFRO	2	RIFRO	0
				FROFRO	4	FRIFRO	0
				RORI	8	RIRI	72
				FRORI	0	FRIRI	2
				ROFRI	7	RIFRI	14
				FROFRI	1	FRIFRI	1

As might be expected the largest number of bushes are found in the two groups N O N O and R I R I, showing the association of normality with freedom and Reversion with presence of Big Bud.

Table 3 shows a condensation of this table and the association of 0 (absence of Big Bud,) and of I (presence of Big Bud), with the three classes of Reversion.

TABLE III.

Occurring in class	Percentage of 0.		Percentage of 1.	
	1st year.	2nd year.	1st year.	2nd year.
N ..	69	84	17	20
F R ..	18	9	7	22
R ..	13	7	76	58

In both years the largest percentages are N with O, and R with I, but it is also clear that other combinations occur in numbers in

excess of experimental error. The average percentage of F R O is 13·5 and of R O, 10, which indicates that an appreciable percentage of bushes free from Big Bud are partially revert, or revert. That this is so, is of course, not surprising in that it is known that mite-free cuttings from reverted bushes remain reverted.

The average percentage for N I is 18·5. This indicates that bushes may be attacked by Big Bud and yet remain normal. This fact was brought out in Table 1, but it was there shown that bushes remain normal only when Big Bud infection was slight.

In Table 4 the facts are regarded from a different point of view. Here, in the upper half, the percentages of first year normals, fractionally reverts and reverts that become normal, fractionally revert and revert in the second year, are noted. In the lower half the numbers are further analysed. The upper half brings out the facts that normals tend to remain normal and reverts, revert. It also shows that fractionally reverts tend to become normal in the second year and that only a small percentage become completely revert. It is clear that the condition of fractional Reversion is a temporary one in most cases. It may represent several possible different states; a bush may be recovering from true Reversion, or part only of the bush may be attacked by Reversion, or the whole bush may be showing a partly reverted type of leaf due to temporary conditions of growth stimulus.

In the lower portion of the table a comparison is made between the second year behaviour of bushes that are, or are not, attacked by Big Bud.

TABLE IV.

Percentage in first year of	Becoming in second year N.	F R.	R.
N	85	11	4
F R	72	19	9
R	4	20	76
N O	86	9	5
N I	79	21	0
F R O	74	22	4
F R I	67	11	22
R O	9	41	50
R I	2	16	82

Here the association of I with N (that is the difference in the subsequent history of normal bushes not attacked and attacked with Big Bud) causes a depletion in the second year N's and R's, and an increase in the second year F R's.

The association of I with F R, causes a depletion for the second year N's and F R's and an increase in the second year R's.

The association of I with R, causes a depletion in the second year N's and F R's, and an increase in the second year R's.

These changes can be diagraminatically represented thus :

$$\begin{array}{rcl} \text{N I} & \text{causes} & \begin{cases} \text{N}\rightarrowtail\text{F R.} \\ \text{R}\rightarrowtail\text{F R.} \end{cases} \\ \text{F R I} & \text{,,} & \begin{cases} \text{N}\rightarrowtail\text{F R}\rightarrowtail\text{R.} \\ \text{F R}\rightarrowtail\text{R.} \end{cases} \\ \text{R I} & \text{,,} & \begin{cases} \text{N}\rightarrowtail\text{F R}\rightarrowtail\text{R.} \\ \text{F R}\rightarrowtail\text{R.} \end{cases} \end{array}$$

Broadly speaking, therefore, an attack of Big Bud always causes a bush to move in the direction of Reversion. The only exception in the above table is in the first year normals which, not attacked by Big Bud gave 5% reverts, and attacked 0%. The percentage only represented four bushes and is not beyond the limits of experimental error.

Conclusions.

This statistical examination brings out the following facts for the bushes under observation.

(1) That normal bushes are generally free from Big Bud infection, but may be slightly attacked.

(2) That reverted bushes are usually attacked by Big Bud, but that an appreciable percentage are free.

(3) That bushes moderately strongly attacked by Big Bud are always reverted.

(4) That it is thus possible to have very reverted bushes that are not attacked by Big Bud, but not possible to have bushes heavily attacked by Big Bud that are not reverted.

(5) That Big Bud attack in the first year causes a bush to become more reverted in the second year than if it had remained free from Big Bud.

THE INFLUENCE OF REVERSION (NETTLE LEAF) ON SUCCESSFUL BLACK CURRANT GROWING.

By A. H. Lees.

For some years past black currants have made very good prices in the open market, sufficiently good indeed to tempt many who lacked adequate experience to try their culture. While some have succeeded many have encountered failure through lack of sufficient knowledge of the essentials for success. As a result of the efforts of various workers during the past few years these essentials are now much more clearly defined than hitherto, and it is possible to give some definite information to guide the prospective grower. On such points as soils, pruning and to some extent manuring, information is already available and it is not proposed to discuss these factors here. One may presume that the prospective grower either possesses, or can obtain such information. The two greatest difficulties are the selection of the right variety and control of disease. Hatton* has shown, and the general experience of the best growers agrees with him, that the varieties belonging to the Baldwyn group are very decidedly the best croppers. These are however, perhaps more liable to disease than some of the other types, and it is disease that is usually the greatest hindrance to the production of profitable crops.

The most serious diseases of the Black Currant are undoubtedly Big Bud and Reversion, the latter being especially destructive. Evidence is accumulating that the two diseases are very closely connected and that the presence of Big Bud, when it has obtained a good hold, is always accompanied by Reversion.

It does not follow, however, in the absence of Big Bud that Reversion is absent. Bushes showing no sign of mite attack may be, and frequently are, reverted. The position, therefore, appears to be that a bush may be reverted without Big Bud, but that the presence of Big Bud increases the amount of Reversion.

Reversion is thus more feared amongst growers than Big Bud,

* *Journal of Pomology.* Vol. II. p. 160.

because a reverted bush means a big loss of crop, while a big-budded bush, if in the initial stage only means a small loss. It is clear, therefore, that Reversion is the most important factor of all in the success or failure of black currant growing.

The problem before the grower is twofold. First he must obtain nursery stock that is free from Reversion and secondly he must keep his plantations free from the presence of reverted bushes. To obtain free stock the cuttings must be taken from bushes that are not reverted and they must be kept clean in the nursery, until the grower obtains possession. The best nurseries endeavour to do this, but not always with complete success. One method is to take cuttings only from fruiting bushes. At first sight this would appear to guarantee success, but in practice complete freedom is not obtained by this method. It is quite possible for a single branch only of a bush to be reverted, or for Reversion to have entered so recently that fruiting is not affected.

In either case there is a danger of some of the cuttings subsequently showing Reversion. Again it is the practice of nurseries that are short of stock to take cuttings from plantation bushes, and from one or two year old cuttings and not only from their stool beds. These one or two year old cuttings or plantation bushes may have contracted the disease after they were planted even though clean at their start. Finally, bushes bought in from other sources and not raised on the spot are specially liable, since in many cases little care has been taken to keep them free.

It is thus clear that the only satisfactory way for nurseries to produce clean stock is to take cuttings from stool beds only, until such time as they have eliminated the disease from their grounds. Even then it is safer to keep to stool bed propagation only, since there is always a possibility of the disease being contracted in the cutting beds. There are two possible ways to test the stool beds. The first is to let one or two canes in each stool stay for two years so as to fruit. Those that drop their fruit should be grubbed. In this way the worst examples will certainly be eliminated, but it is possible, though not certain, in the present state of knowledge that intermediate types will not be noticed.

The second way is the method described in the Report for 1920. This method depends on leaf character and may be employed during several weeks of the growing season. It does not interfere in any way with the growing of the stools for cuttings, and is thus a method that can be used every year. It enables the observer to find slightly affected cases, as well as pronounced ones, and thus is more rigorous than the first method. Needless to say in rogueing stool beds, even suspicious cases should be removed.

Employment of such methods to the stool and cutting beds would enable nurseries to send out absolutely healthy stock. That this

is not so at present is shown by experience of bought-in plants at Long Ashton. The plants were obtained from nurserymen and growers of good reputation, and no attempt was made to hide the fact that they were for experimental purposes. Out of 612 bushes that were planted, 57, or 9% were reverted the following year. Of these, 142 bought from a grower produced 35 reverts, or 25%, and 470 from first-class nurserymen produced 22 reverts or 5%. It is clear, therefore, that at the present time the prospective grower cannot depend on obtaining completely healthy stock, even from good nurseries. It is highly desirable that nurserymen in general should evolve or submit to some scheme, which would ensure the production of healthy stock only.

After obtaining healthy stock the grower has still to face the problem of keeping his plantations healthy. This clearly involves a knowledge of how the disease obtains access to healthy bushes. It is an acknowledged fact that Reversion and Big Bud are often closely associated. Further it has been shown in another article of this Report that the presence of Big Bud increases the amount of Reversion and the absence decreases the amount. In another paper* it has also been shown that if any shoot, previously healthy, is attacked by mite it has a tendency to produce reverted leaves and that this tendency is greater, the greater the infection of mite. There is, therefore, a strong probability that Reversion starts on a healthy bush, when that bush is subjected to mite attack. A few bushes under control have become reverted in the second year, after being normal and free from Big Bud in the first year, but the percentage was too small to rely on freedom from personal error. It is probable, therefore, though not certain, that it is chiefly through mite attack that Reversion gains access to healthy bushes. The grower, however, is not yet in a position to control mite attack by spray methods, and therefore his only chance of keeping his plantations free from reverted bushes is by rogueing. Reverts may be identified easily by the leaf-vein method, and their removal need not take place till after their crop, such as it is, has been gathered.

The place of such bushes must be filled in the following autumn from cutting beds which every grower should keep going. Not many cuttings need be taken every year, but only marked, healthy bushes should be used for the purpose. The cutting beds also should be carefully rogued. The method has already been tried by one grower with considerable success. In addition Big Bud has practically disappeared as the result of the treatment, a fact which supports the idea that the first signs of Reversion in a healthy bush are due to mite infection.

RED PLANT DISEASE OF STRAWBERRIES.

By A. H. Lees.

This disease of strawberries has been reported to the Bristol Advisory Centre by Inspectors of the Ministry working in the Southampton, Cheddar and Tamar Valley districts. The name may cover one or more diseases, but as the purpose of this report is not explanatory, but merely informative the name is used regardless of its possible accuracy.

Distribution.—The disease has been seen in the Southampton, Cheddar and Tamar Valley districts, but not in the strawberry growing regions of Herefordshire and Worcestershire. There is reason to suppose that the disease at Cheddar is of a different order from that of the other two districts.

Damage Done.—This is serious around Swanwick, though it is impossible to assign percentage figures to the disease. Judging from growers' reports it is also serious in the Tamar Valley, but this district was not so extensively surveyed as that of Southampton. It is safe to say, however, that in both districts it is the most serious factor limiting the profit of strawberry growing.

Symptons.—In these two districts the disease turns up in definite patches. These patches are rather irregular in shape, though sometimes roughly circular, sometimes oval. The limitations of the patches are not clearly defined, but usually shade off rather abruptly into the normal. In size they vary from about 4 square yards to about 40 square yards. The distribution of patches is irregular. Fresh runners planted in such patches grow almost if not quite normally during their maiden year. In the second year they become very much checked and this check is accompanied by very feeble root development from the new crowns. In the third year they either die outright, or remain in a very checked condition. They may even die in the second year. If replanted with local runners these patches reappear in the second year. If non-local runners are used the same thing happens, but the effect is not so marked.

History of the Patches.—No certain information can be obtained, but the general opinion is that they are not getting less in size, but if anything are growing. They certainly reappear year after year if planted with strawberries. One case in the Tamar Valley is of special interest. The field had been thirty years in grass, then three years in strawberries and a patch was very well defined.

Possible Causes—

(*a*) *Lack of Lime.*—At first this appeared as a possible cause, but soil analysis and liming experiments have practically ruled this out.

(*b*) *Lack of Manuring.*—The patches have received the same manuring as the normal parts (at Swanwick generally town dung). It is not likely, therefore, to be due to insufficient manuring.

(*c*) *Eelworms.*—Neither at Tamar nor Southampton could parasitic eelworms be found in the affected plants. At Cheddar eelworm was found, but no "patches." Such plants occurred irregularly in the row and the disease appeared to be of a different order from the "patch" disease of Southampton and Tamar Valley.

(*d*) *Soil.*—It is possible that the mechanical make up of soil or subsoil is responsible for these patches, but no analytical evidence is yet to hand. Both Tamar Valley and Southampton soils are light, while in Worcestershire and Herefordshire, where the disease does not appear, they are heavy.

General Irregularity of Plant.—Apart from the definite patches the most striking feature of Southampton and Tamar Valley strawberry plantations is the variation in size of plants of the same age in the rows. The growers do not complain of this, but it is evident that this is also limiting the size of crop per acre. The irregularity is not confined to patches, but extends everywhere, and the difference in size in neighbouring plants is often very marked. Plants from local sources suffer far more than plants obtained outside the district. The evidence for the influence of land long under strawberries or newly so is not nearly so clear. If anything plantations on newer lands are better, but these lands are also often slightly heavier. A superficial view tends to the idea that the local strains are degenerating in vigour.

SPRAYING TRIAL FOR CONTROL OF LOGAN BEETLES.

By A. H. Lees and G. S. Peren.

In view of the results obtained last year, which appeared to indicate the desirability of giving three arsenate sprayings to cover more fully the somewhat prolonged blossoming season of the loganberry, the following trial was carried out.

Twelve rows of logans were used. Three-quarters of each row were sprayed and the remaining quarter left as control.

The first spraying was applied when approximately one third of the blossom was out, the second, when two thirds were out, and the third when the bushes were in full bloom.

The following formula was used :—

Arsenate of Lead	4lbs.
Water	100 gallons.

Pressure of application 215lbs. per square inch.

First application	May 18th.
Second ,, ...	May 24th.
Third	June 2nd.

The results obtained are set out in Table 1.

From these figures it will be seen that the sprayed berries averaged 4·4% infected, while the unsprayed averaged 19·8% infected.

In estimating the value of the treatment the last four pickings may reasonably be left out of account, since the first eight cover the important bulk of the crop and the last four merely represent the scattered fruit from very late flowers. The pickings on July 18 and 20th were hardly worth the expense involved.

If then the figures of the first eight pickings are taken, it will be seen that the total average of infected berries is 3·5%, for the sprayed, as against 20·7% for the unsprayed, which represents a very considerable improvement in market value.

Referring to the column showing the percentages infected per picking, it will be seen that in the case of the sprayed berries, there is a steady increase from ·3% to 11·6%, with the exception of the

pickings on July 1st and July 18th, and the slight drop on July 7th. On the other hand the unsprayed berries show heaviest infection, *i.e.*, 27·5% at the third picking, on June 29th, and again an almost equally heavy figure of 27·3% on July 4th, after which the figures tend to decrease. The six pickings from June 29th to July 11th inclusive, show the worst effects and it may, therefore, be taken that this period represents a period of similar length of time when the major part of ovipositing took place.

There is practically no correlation between the two columns of percentages infected, except for the small mutual drop on July 1st, which may have been due to weather conditions at the corresponding egg-laying date. This general lack of correlation and steady increase of the figures for the sprayed berries may possible be explained by the fact, that the first third of the blossoms received three sprayings, the second third two sprayings, and the final third one spraying. One might thus suggest that the first two pickings show the full effect of three sprayings, the third, fourth and fifth pickings, the result of two sprayings, and the sixth, seventh, eighth and ninth the result of only one spraying. In the absence, however, of laboratory control these ideas must be regarded as tentative. As the period of time covered by the application of the sprayings was only 15 days, and as it was observed that a certain number of very backward trusses flowered after the last spraying was given, it may be safely assumed that a certain portion of the berries in the last three pickings received no spraying at all. In view of these facts one would expect to find the steady increase shown as opposed to the rise and fall in the figures for the unsprayed berries.

The results obtained are considered quite satisfactory, especially those for the first eight pickings, and in the case of the grand totals 4·9%, as opposed to 19·8%, or 153 berries infected in 3141, as opposed to 672 in 3395, represents a difference which in the crop off even an acre would be of very considerable bulk.

It is hoped that if the same measure of control can be obtained for some three years in succession, it will then be possible to dispense with the spraying for at least one or two years, thus partially compensating for the expense involved in three applications.

TABLE I.

Date of Picking.	Sprayed.			Unsprayed.		
	Sound.	Infected.		Sound.	Infected.	
		Number.	Percentage		Number.	Percentage.
June 23rd.	285	1	·3	302	24	7·4
„ 27th.	378	3	·8	367	58	13·6
„ 29th.	236	9	3·7	195	74	27·5
July 1st.	328	9	2·7	189	51	21·2
„ 4th.	246	11	4·2	282	106	27·3
„ 5th.	271	17	5·9	236	80	25·3
„ 7th.	269	15	5·3	236	73	23·6
„ 11th.	274	19	6·5	275	79	22·3
Totals	2287	84	3·5	2082	545	20·7
July 14th.	313	22	6·6	279	52	15·7
„ 16th.	113	14	11·0	115	24	17·3
„ 18th.	131	14	9·6	109	20	15·5
„ 20th.	144	19	11·6	138	31	18·3
Grand Totals	2988	153	4·9	2723	672	19·8
Numbers examined ..	3141			3395		

CANKER CONTROL TRIALS.

By S. P. Wiltshire.

Concurrently with the investigations in progress on apple canker, in relation to the problems of mode of entry of the fungus into the tree, the sequence of events after entry and the conditions affecting the degree of resistance of the host, annual spraying trials are also being conducted. The results of the work under the former head, ready for publication, have recently been described in a paper contributed to the Annals of Applied Biology (Vol. VIII, Page 182, Nov. 1921), and the present note is, therefore, concerned solely with the results of the spraying trials made during 1921.

The trees used for the main experiment were again the highly susceptible Kingston Black and Medaille d'Or seedlings. Owing to the fact that infection of the 1919 wood did not take place until as late in the winter season as the end of March, 1920, the spraying in the following winter trials, was delayed until 3rd February, 1921, when a first spraying was given with copper stearate. By the end of March, 1921, only ten leaf scar infections had occurred and consequently a second spraying with Burgundy mixture was given on April 1st, 1921.

The method adopted in these trials was rather more exact than that of the previous experiment. One hundred vigorous shoots formed in 1920 were selected and labelled, twenty shoots being selected on each of five trees. Ten shoots on each tree were sprayed and ten left unsprayed. The latter were covered with newspaper while spraying was in progress and thus protected from any spray fluid which might otherwise have fallen on them in spraying the other ten shoots. These temporarily covered shoots naturally served as controls. Counts were made on 31st March, 1921, 19th August, 1921, and again on 23rd January, 1922. The final results were as follows :—

Tree.	Unsprayed.	Sprayed.
1	2	1
2	3	2
3	2	6
4	0	2
5	2	5
	9	16

The count on 19th August, 1921, gave two cankers less, one on a control branch and one on a sprayed branch.

The first fact to notice in connection with these results is the small number of infections compared with those of previous years. The figures of the spraying given in last year's report were 179 on the sprayed and 500 on the unsprayed branches, and whilst these figures are not actually comparable as they refer to a smaller number of larger branches than used in this year's experiment, they suffice to show that leaf scar infection was general as it has been each spring for a number of years on these trees. The reason for the small infection of 1921, was probably the very dry summer experienced in that year. Many observations point to the fact that canker is much more serious under wet conditions than under dry ones. In the eastern part of England, where the rainfall is considerably less than in the west, canker is not nearly so prevalent, and in Ireland, where the climate is even wetter than in western England, such a resistant variety as Bramley's Seedling becomes subject to canker. Reference may here be made to some experiments carried out some years ago to determine the effect of soil moisture on the incidence of canker.

Six pot plants, four of Allington Pippin and two of Lord Suffield were inoculated through deep wounds, each in 15 places, with conidia of *Nectria galligena*, Bres. Two trees of Allington Pippin and one of Lord Suffield were given excess of moisture by immersing the pots in buckets containing water. They were taken from the buckets and allowed to drain for one hour each day. The remaining three trees were placed on the surface of the soil in the same plot and given a little water each day. Pieces of wood prevented any rain from reaching the soil in the pots. The inoculant used only contained a comparatively small number of conidia, the object of this being to intensify any effect on the infection which the treatment of the host might produce. The experiment was started on 30th July, 1915, and the following results were obtained by 31st August, 1915.

Variety.	Wet.		Dry.	
	Successful Infections.	*Average length of Canker.*	*Successful Infections.*	*Average length of Canker.*
Allington Pippin ..	11 out of 15	2·9 cms.	7 out of 15	1·2 cms.
Ditto ..	15 ,, ,, 15	2·1 cms.	4 ,, ,, 15	1·6 cms.
Lord Suffield ..	Tree died.	——	6 ,, ,, 15	1·6 cms.

From this one gathers that the number of successful inoculations is increased by wet conditions of the soil and that the growth of the fungus in the tissues is more rapid in the case of trees growing

in a wet soil. What part a wet atmosphere has on the infection of canker has not been determined, and it is probable that this is even more important than wet soil conditions.

The only other point calling for notice in connection with the spraying trial mentioned above, is that the cankers on the sprayed branches were more numerous than those on the unsprayed. In view of the abnormally low figures obtained in either case as compared with previous years it is exceedingly doubtful if any significance should be attached to the 1921 results, in respect of the utility of winter spraying. The probability is that the weather conditions did not permit of a real test: and with these apparently affecting the extent of natural infection to so marked a degree, it is clear that a decision as to the efficacy of this method of control can only be arrived at after trials conducted over a series of years.

In addition to the spraying trial mentioned above, another was made on a large scale in a plantation of young bush apples. Three rows were sprayed with Burgundy Mixture on December 23rd, 1920, and three left unsprayed. Each row consisted of 20 trees of 20 different varieties, each variety being arranged crosswise across the plot. Counts made in November 1921, gave the following figures, omitting any cankers on the 1921 wood :—

		Total.	*Leaf scar infections*	*Canker imperfectly cut out previous winter*	*Other types of infection*
Sprayed	Row 1 ..	7	4	—	3
	„ 3 ..	12	3	8	1
	„ 6 ..	15	4	9	2
		34	11	17	6
Unsprayed	Row 2 ..	19*	15	4	
	„ 4 ..	14	5	5	4
	„ 5 ..	21†	5	3	13
		54	25	12	17

* 12 on one tree, 5 on another.
† 17 on one tree.

The number of leaf scar infections was again small in comparison with what one would expect in a rainy season. One striking feature was the large number of cankers which developed from old cankers which had been imperfectly cut out. Before the experiment started the whole of the cankered material was very carefully removed from the trees and the wounds covered over with tar. In many instances the tar coating had remained, although canker had developed and the probability was that the infected material

had not been completely removed. This emphasizes the necessity for thorough treatment in cutting out cankers, the only really sound plan to go upon being to cut well into the healthy wood to ensure complete removal of the fungus.

The figures themselves are not sufficiently regular for much significance to be attached to them. The marked susceptibility of one particular variety stood out strongly as compared the with others, the single tree of this variety in row five bearing 17 cankers, whilst the remaining trees of the row bore only four. The practice of trying spraying trials on mixed plantations of many different varieties is open to serious objections and one feels that much more valuable and reliable information can be obtained by the method adopted in the main trial described above, than by larger field trials with mixed varieties in which many factors come into play and tend to obscure the real result.

THE MICHAELMAS DAISY DISEASE.

By S. P. Wiltshire.

This disease, the causal fungus of which was first isolated at this Station in July, 1920, has been the subject of further limited enquiry during the past summer. A number of inoculation experiments have been carried out, the details of which are as follows :—

During the winter of 1920–21, Michaelmas Daisy plants were potted up and placed in a green-house. Between 19th October, 1920, and 8th November, 1920, five inoculations were made through wounds and five similar wounds were left untreated to act as controls. Two of the inoculations were cut on 24th November, 1920, when they were 36 days old and neither showed any sign of infection. Throughout the spring of 1921, none of the three remaining inoculated shoots showed any signs of the disease, but in August, 1921, two of them were found to be dead and infected with a vascular fungus.

The next experiment was carried out on six Michaelmas Daisy plants in pots. The fungus used was the original strain isolated in 1920. The method of inoculation was to transfer portions of the mycelium to wounds made in the stem. The outside of the stem was first cleaned and sterilised by washing and flaming, and cuts were then made by a scalpel, which was kept in alcohol and flamed before use. After inoculation raffia was tied finally round each wound in order to keep it clean and as moist as possible. Only main shoots about 18ins. high were chosen for experiment and the wounds were made about 6ins. from the ground. Control shoots were treated exactly the same as inoculated ones except that no inoculant was placed in them. Ten inoculations were made on 8th June, 1921, and a similar number of controls as inoculations were made on each plant. Twenty-one days later no definite signs of disease were visible, although some of the leaves on the inoculated shoots showed slight signs of scorching. On the 9th July, 1921, the lower leaves on the inoculated shoots were turning reddish yellow in many cases, and on the 13th September, 1921, the following records were made. Each one of the control shoots was healthy. Some

of the infections were much more advanced than others, the most backward simply showing two leaves withering at their tips, whilst the most advanced showed practically the whole shoot dead and young healthy shoots springing up from the base. A photograph of one of the plants used in the experiment is given in Fig. 1. The two outer shoots were inoculated and both showed marked signs of the disease, the left one being quite dead. The two central shoots were controls and remained quite healthy. The photograph was taken on the 10th October, 1921—four months after the inoculations were made. Towards the end of the summer three out of the ten control shoots became infected with the fungus and finally showed well defined symptoms of the disease. The manner in which these control shoots became infected is open to some doubt, but probably the conidia arising from the inoculant used in making the inoculation was carried to the wounds of the controls. The stock plants used for the experiment were derived from plants grown in the Station for years and which never previously showed signs of the disease. In making the wounds every care was taken to keep them as sterile as possible, as described above.

The course of the disease as shown by the inoculated shoots was as follows :—The first signs of successful infection was shown by the leaves on the main stem of the inflorescence and these turned an unhealthy colour with a blackening and drying at the edges. The withering then usually occurred on some of the leaves of the flowering shoots. Frequently the affected shoots were confined to the side of the inflorescence above the inoculation. Affected shoots gradually became more and more browned and dried up until the whole was completely dead. Young shoots then sprang up from the base in exactly the same manner as occurs in the naturally infected plants.

Portions of the stems inoculated in this experiment were finally placed on agar in Petri dishes and a fungous mycelium developed similar to that which was used in the inoculations.

The third experiment consisted of ten inoculations and ten controls and were made in an identical manner with the second experiment, except, that the inoculations were made later in the season, viz., 29th August, 1921—2nd September, 1921, and also small branches of the inflorescence were treated instead of the main stem. The strain used was a recent isolation from diseased material. On the 16th September, 1921, viz., after 18 days incubation, the first signs of disease were noted, the large leaves on the main stem dying off. On the 10th October, 1921, each of the inoculations could be clearly distinguished from the controls, with the exception of one control, which showed slight yellowing. The final result obtained on 10th November, 1921, showed ten of ten inoculations being successful, whilst two out of the ten controls showed slight symp-

toms. The infection of the controls was again a disturbing factor and shows how readily infection of suitable wounds can take place.

The results of these inoculation experiments show that the fungus isolated is probably the causal organism of the disease. Only one kind of fungus has ever been isolated from Michaelmas Daisies affected with the disease here treated of and there has been no difficulty in obtaining it. The naming of this fungus has not been carried out as it was decided first of all to establish its pathogenicity.

In a recent paper by Dowson to the British Mycological Society, a report of which appeared in the "Gardeners' Chronicle" for February 11th, 1922, a reference is made to the fact that the fungus isolated by him from diseased Michaelmas daisies apparently differs somewhat from the one isolated at Long Ashton. The original culture received from Mr. Dowson in exchange for the Long Ashton strain was proved ultimately to be non-pathogenic, whereas the second isolation received from him resembles very greatly the one isolated at Long Ashton, although further cultures will be necessary to establish the identity.

Fig. 1. A Michaelmas Daisy artificially infected with the disease fungus in the two outer shoots, the two central control shoots remaining healthy.

Fig. 1.

Artificial Production of Wilt Disease of Michaelmas Daisy.

LEAF SCORCH ON FRUIT TREES.

By B. T. P. Barker, A. H. Lees, T. Wallace and S. P. Wiltshire.

In the Annual Report of this Station for 1913 a short note describing the action of wind in producing scorching of the foliage of apple trees was included. It was shown there that in the course of leaf movements caused by wind a considerable amount of rubbing of leaf surfaces takes place, resulting in changes occurring at the chafed parts which ultimately end in scorching effects. A further article in the Annual Report for 1916 deals with another aspect of apple leaf scorch, the trouble there considered being associated with certain soils, which will be referred to subsequently for convenience as "scorching" soils. The investigations at that time did not reach a final conclusion and, therefore, as opportunity arose subsequently, further observations and experiments have been made. Until 1921 circumstances did not permit of the carrying out of any extensive scheme of work. During the latter year, however, so much additional information has been gained that, although supplementary experiments in certain directions are still necessary, it is desirable to report progress and summarise the position now reached.

The scorching of foliage is not confined to apple trees. It appears, as will be shown, on fruit trees generally and on many other trees, shrubs, and even herbaceous plants. It is also evidently brought about by a variety of conditions, to which passing mention, at least, will be made in due course. A number of papers bearing on various aspects of the subject have previously been published by different investigators. One of the most recent, that by L. A. Boodle, in the Journal of the Ministry of Agriculture, August, 1920, on "Scorching of Foliage by Sea Winds," may be specially mentioned, since it includes a review of previous work and deals mainly with a side of the question, viz., the direct action of drying winds, which has not been conspicuous in our own work. Other references to the literature of the subject can be more suitably made during the course of the account of our investigations which follows.

At the outset a description of the observations made by direct examination in the field on scorching associated with scorching soils will be given. This involves to some extent a recapitulation of data already published in the paper in the Annual Report for 1916, in order to make the present account more comprehensive and complete.

Description of Disease in the Field.

Plantations suffering from the disease can usually be picked out at some distance. There is a general brownish tinge of the foliage, as opposed to the healthy green of normal plantations. A closer view of the trees shows that affected trees are more or less stunted in comparison with healthy ones. The amount of stunting varies, in some cases it is hardly evident, whilst in others it is so excessive that trees 15 years old are only as large as normal trees of five. The length of shoot tends to be small, and in the extreme cases not more than half an inch of shoot growth may be made every year. It is, however, the leaf character that is the most obvious sign of the disease. Affected leaves appear to have their margins scorched as if by fire. In fully developed specimens the scorched margin may extend to as much as half an inch in width, leaving only a small axial portion still green. The scorched margin is dark brown in colour, and of a dry shattery texture. The full development of the scorch is usually confined to the older leaves though signs of attack may usually be seen in the younger leaves as yellowish green areas round the margin. As the leaves get badly attacked they show a great tendency to fall. The incidence of the disease usually synchronises with the advent of dry summer weather, from the end of May to the end of June, though it is not necessarily confined to this period. After this dry period has passed and summer rains have occurred the trees often make a fresh growth, which remains healthy and shows no sign of scorch. If the whole season is moist scorch either fails to develop on typical scorch plantations, or, it is very much reduced in intensity. Occasionally trees may be found which develop a comparatively sudden attack late in the summer, and a somewhat similar form is often seen in the autumn, just prior to leaf-fall. These two forms, however, are not typical, and do not cause any serious damage to the trees.

While the more obvious damage is shown by the aerial part of the tree, the roots of leaf scorch trees are also suffering. This is apparent if the trees are swayed to and fro, when, in nearly every case, the root proves to have but a poor hold on the soil.

The disease is most frequent on arable plantations and its presence on apples grown in grass is rare. Scorch cases on grass are, however, not altogether unknown, though the intensity is not then

very great. The influence of root-stock is well marked, though to some extent this is confused in the field by the fact that trees in grass orchards are nearly always on the free stock, and that standard trees are not so common in arable orchards as are bush trees. Cases have, however, been seen where bush trees on free stock have shown a freedom from the disease, whereas those on Paradise in the same field were badly attacked. Similarly cases have been seen where standard trees on free stock, grown in an arable plantation, have been scorched. There is little doubt, therefore, that on the whole, both the free stock and the presence of grass tends to prevent the disease.

In most affected plantations the intensity of disease varies from place to place. Usually there are no really well defined areas of scorch, with sharply marked margins. Seen from a distance a scorched area might be picked out as contrasting with an unscorched one, but a closer view generally shows that on the margin of such areas there are trees which show a small amount of the disease which is unnoticeable except on a close view. As a general conclusion, therefore, it may be stated that the disease occurs in patches of various sizes, but that these patches have no sharp outline, but pass almost insensibly into the normal.

While the disease is most commonly reported on apples, many other kinds of fruit may suffer. It has been found also on plums, pears, red currants, black currants, gooseberries, apricots, many forest trees, as well as on vegetables, such as broad bean, runner bean, mangolds, and rhubarb.

Details of Cases in the Field.

The disease has appeared in many soils of the west and south-west. One if the first reported cases appeared on the river gravels overlying Lower Lias, in Worcestershire. Here both Worcester Pearmain and Grenadier were attacked. The latter were grubbed, but the former were allowed to remain, and have suffered every year for a number of years. The disease did not reach its full intensity, but the stunting conditions were developed sufficiently to force the trees into abundant flowering without a corresponding set of fruit.

Cases A, B, and C* are a group of plantations all of which show scorch to some extent. The soil type is similar to the first case quoted, though rather more marked in its characters. These soils are all coarse textured and full of round pebbles.

In Case B most of the commercial dessert and culinary varieties

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* Cases marked with letters are afterwards treated in greater detail in the portion dealing with the soil characters.

were represented, and the scorched area was fairly definite, though isolated affected trees occurred in other portions of the plantation.

In Case C the influence of the underlying clay was particularly interesting. The plantation is on a slope, and towards the bottom the lias clay comes to the surface. The line of junction of the light and heavy soil is, of course, not sharp, owing to the mixing that has taken place from rain action. On the plantation all the trees were supposed to be on the free stock and no definite scorch area could be observed, the affected trees occurring at intervals over the plot, but only on that portion which was on the lighter type of soil. The variety most affected was Lord Grosvenor, and these were growing adjacent to Newton Wonder, which showed no scorch at all. This plantation differed from others in this group in that none of the trees were badly stunted.

Case E.—This plantation consisted of Worcester Pearmain, Cox's Orange Pippin, James Grieve and Rival. All were on the Paradise stock and all were scorched, the Cox and Worcester bushes being the worst. They were planted in late 1919 and early 1921, the 1919 trees being allowed to fruit in 1920. All were quite loose in the soil when shaken. The surface soil was of a light stoney character and varied in depth over the plot. At the north end it was as shallow as 4 inches, but increased to 12 inches depth at the south end. The subsoil of the whole plot appeared to be of a gravelly nature. The trees on the shallow soil were affected to a greater extent than those on the deeper soil.

These cases, A—E, were all light surface soils, and it is particularly in this class that the disease is likely to appear. Before passing on to cases on medium loams, one more case will be described. This was investigated some years ago and no soil data are available other than those obtained from a purely superficial view. This case was particularly interesting by reason of the many soils and subsoils involved.

The varieties included most of the ordinary commercial ones, even Bramley, and they all showed scorching when grown in the scorch patches. These scorch patches were particularly noticeable on the shallower portions. As the depth increased scorching became less and less marked. On one side of the plantation there was a foot of peat over an inch of stiff clay, over a fairly gravelly subsoil. A little way off the soil was a peaty loam over a calcareous gravel that was nearly as hard as a pavement. Still further, the soil was a light gravelly loam over pure gravel. On all these situations trees scorched, the disease being especially bad over the gravelly portions. The most interesting fact, however, about this case was the behaviour of a standard tree, of which there were a few amongst the bushes. The stem of the tree had been bored and destroyed by Goat Moth, and, in consequence, the whole head had been des-

troyed. Dormant buds, however, below the injury, but still on the scion, had been forced into growth, and these had reformed a bush. This bush never scorched, though on a scorch patch. Here the influence of the free stock was clearly shown.

The next two cases appeared on soils that would ordinarily be described as medium loams.

Case F.—This plantation consisted chiefly of bush trees on the paradise stock. The disease was worse over one large patch, but was not confined to it. The trees were regularly manured in winter with watery extract of cow manure, and bore large green leaves, which were nevertheless markedly scorched. Black currants growing in the scorched area were also strongly scorched. In some positions onions showed the bad conditions through the sickly appearance of the foliage, though in their case no actual scorch was produced. Standard apples on grass near by were unaffected, but one standard tree in arable land was scorched.

Case G.—This case occurred on a medium loam, with nothing to suggest leaf scorch conditions. The trees were about ten to fifteen years old, half standards, and of the usual commercial varieties. They were markedly loose in the soil.

Case H.—This consisted of two plantations, each several acres in extent and each on a deep heavy loam soil. Though the plantations were only separated by a windbreak the scorching was confined to one. In both cases the trees were on paradise stocks, and included most of the ordinary commercial dessert and culinary varieties. The affected trees on the scorch plot varied greatly, some had made scarcely any growth since they were planted, whilst others were almost normal size for their age. All the affected trees showed the characteristic looseness on being shaken, which denotes bad root formation. The soils of both plots appeared to be identical in appearance, and the field examination did not bring out any difference. The grower who has spent much time in attempting to discover some point of difference between the two soils, has failed to do so, either in appearance or in working. Both plots have received the same manurial treatment. Previous to planting the trees good crops of cereals had been grown on the plots.

Case I.—This plantation was on a rather heavy loam, which becomes very sticky in winter, and approximates to a clay in general appearance. It would be described as a deep heavy loam. The usual effects of the disease were observed.

Case J.—This plantation is about five acres in extent. The scorch area is largely confined to about an acre in it. The grower has observed that the scorch had first appeared on the trees in the centre of this area, when the trees were quite young, and that the area had gradually extended radially, the trees in the centre being affected to a greater extent than those nearer the outer edges. The

trees are now 20 years of age, and in the centre of the area some of the trees are only about four feet in height, while those slightly affected are almost normal in size. On the intermediate and smallest trees the leaves are below normal size. All are on the Paradise Stock. The soil has the appearance of a deep heavy loam, and there is nothing in its appearance to suggest that it would be unsuitable for fruit growing. The trees in the centre of the patch are Cox, Worcester and Bramley, the Cox trees being in the worst condition.

General Conclusions from the Field Examination.

(*a*) Scorched trees are more or less stunted in growth.

(*b*) Scorched leaves may be either large or small.

(*c*) The roots of scorched trees are nearly always loose in the ground.

(*d*) Scorching takes place during the summer drought.

(*e*) That in a moist season it is nearly, or quite, absent.

(*f*) That a second growth free from scorch usually occurs after heavy summer rain.

(*g*) That scorching is usually, but not entirely, confined to light soils.

(*h*) That scorch areas generally occur in fairly, but not sharply, defined patches.

(*i*) That apples on free stocks very rarely suffer from scorch.

(*j*) That apples on grass land very rarely suffer from scorch.

(*k*) That beside the apple, plums, pears, gooseberries, black and red currants and apricots, suffer.

The Characters of Scorching Soils.

The two characteristic features of trees suffering from leaf scorch, viz., the looseness of the trees in the ground and the scorched appearance of the leaves, are suggestive of poor root development and of the failure of water supply to the leaves.

Observations made in the field on the soils of the leaf scorch areas showed that in the majority of cases the soils were of a light, sandy character, and were often very stony. In a few cases the soils appeared to be fairly light loams of less coarse texture than those mentioned above, whilst another group appeared to be heavy loams of good depth and very similar to each other, which were decidedly " sticky " in wet weather, and difficult to work.

From the consideration of the above observations, it was thought that the examination of the textures of the soils from the scorch areas down to a depth of a few feet might throw considerable light on the problem, and the plan of work outlined below was accordingly followed.

Whenever it was possible to do so, holes were dug at various points on the scorch plots, generally about 4ft. or 5ft. in depth, or until some well defined change in the texture of the soil was met with. Soil samples for analysis were taken from the sides of these holes as follows :—Surface soil to 9ins. in depth ; subsoil between 9in. and 18in. in depth ; samples below a depth of 2ft. at intervals of 1ft. down to the bottom of the hole.

Complete analyses—mechanical and chemical—were to be carried out on the surface soil and subsoil samples, and mechanical analyses only on the samples below the subsoil.

Further, the growers were to make observations on the amount of water present in the holes during the summer.

Where it was impossible to have these holes dug, samples of the surface soil and subsoil only were taken for analysis. The results of the analyses, as far as it has been possible to complete them up to the present, are given on Page 90, and are discussed in detail below.

The examinations were carried out at 10 centres, denoted below by the letters A to J.

Discussion of Results.

Centres A, B, C.—Geological Formation—" Drift " over Lower Lias.

These three soils belong to the same deposit of " Drift " and are so similar in character that the complete scheme of analysis was only carried out on what appeared to be the most extreme case of the three, the results of the determinations of the stones, fine gravel and coarse sand, moisture and loss on ignition only being given for the second centre, and no results for the third on which the trees are the least affected.

Holes were dug at Centres A and B. At Centre A the surface soil type persisted to a depth of 6ft., at which depth a bed of blue Lias clay was found.

Throughout the summer, water lay in these holes to a depth varying from 6ins. to 18ins. from the bottoms of the holes.

The holes at Centre B were dug to a depth of 4ft, at which depth the soil sample taken appeared to indicate the point of junction of the Drift deposit with the underlying bed of clay. As these holes were only dug at the end of August, no observations were made on their water contents.

With regard to the soil at Centre C it should be stated that this centre is situated near the edge of the Drift deposit and at one end of the plantation the Drift shades off and the Lias clay underlying it appears on the surface. The leaf scorch area is situated at the point where the Drift deposit is deepest.

Centre A.—The mechanical analyses show that down to a depth of 5ft. the soil is composed largely of stones (pebbles) and coarse sand, the former composing 48 per cent of the soil at 3ft.—4ft. in depth, whilst the amount of the latter varies from 51·69% in the surface soil (after the removal of the stones) to 80·72% at a depth of 4ft.—5ft.

The percentage of clay at the various depths is always small, and at 2ft.—3ft. is only 3.28%.

The chemical analyses show a fairly low amount of organic matter present, a low total potash, and high amounts of total and available phosphoric acid in both the surface soil and subsoil.

This plot is used for growing market garden crops, and in the past heavy dressings of shoddy, bone manures, and meat meal have been applied.

The amounts of calcium carbonate present in the surface soil and subsoil are small, whilst the soil below the subsoil is devoid of this substance.

Centre B.—A comparison of the amounts of stones, fine gravel and coarse sand in the samples from this centre with those from Centre A show the following facts.

The soil at Centre B is not so stony as that at Centre A.

The amounts of fine gravel and coarse sand in the surface soil and subsoil at the two centres are practically identical, but at depths below 2ft. the amounts of these fractions present are much higher at Centre A than at Centre B.

The amounts of organic matter present in the surface soils and subsoils at Centre A are higher than at Centre B.

For consideration with these facts it should be stated here that the amount of leaf scorch present at Centre A is greatly in excess of that at Centre B.

Details of the past manurial treatment are not available for this centre.

Soils of the type occurring at these centres would be expected to have poor water-holding and water-lifting properties.

Centre D.—Geological formation—Alluvium over Lower Lias.

This soil forms part of an alluvial deposit of sand. Holes were dug at this centre, and samples taken according to plan to a depth of 5ft.

The mechanical analyses of the fractions show that the soil is devoid of stones, and that to a depth of 4ft. the dominating fraction is coarse sand, the amount of which varies from 51·86% in the surface soil to 68·33% at 3ft.—4ft. At a depth of 4ft.—5ft. a bed of blue Lias clay is reached, and the amount of coarse sand present is greatly diminished.

As in the cases of the soils at Centres A, B and C, one would

expect a soil of this type to have very poor water-holding and water-lifting properties.

The food supplies in this soil are relatively small. The amounts of both total and available potash are low, whilst the total phosphoric acid is only fair and the available phosphoric acid only moderate.

Calcium carbonate is present in small quantities in the surface soil and subsoil, while the sample taken at a depth of 3ft.—4ft. contained 13·4% of this substance. The presence of this large amount of calcium carbonate in this sample may possibly be due to the continued washing down of this material through the coarse textured soil above to the point where its further downward movement would be greatly impeded by the bed of clay lying immediately below.

Centre E.—Geological formation—New Red Sandstone—Keuper Marl.

The soil of this plot is typical of a large area of the New Red Sandstone soils occurring in the district in Somerset, between Minehead and Watchet. It is on the light side and the surface soil contains numerous small flat pieces of sandstone. On digging down, these pieces of sandstone become more numerous until at a depth of a few feet the soil appears to consist almost entirely of stones.

Holes were dug on this plot to a depth of 4ft, and the usual samples taken to this depth. On the day when the samples were taken—October 28th, 1921—the soil, even at a depth of 4ft, was perfectly dry, and the soil on the sides of the holes at any depth could be removed by the hand with the greatest ease. On such a soil as this, one would expect that the trees would have some difficulty in becoming firmly established.

From the mechanical analyses, it will be seen that the percentages of stones in the samples vary from 22·8% in the surface soil to 35·4% at a depth of 3ft.—4ft. Further, the percentages of fine gravel and coarse sand are also high, amounting to 24·07% and 20·32% respectively at a depth of 3ft.—4ft.

The percentage of fine silt present is high in all samples.

From the chemical analyses, it will be seen that the amount of organic matter present in the surface soil is normal for a pasture soil of the New Red Sandstone Formation. The amounts of total potash are only medium in the surface soil and subsoil, while the supplies of available potash are only moderate. The amounts of total and available phosphoric acid present in both the surface soil and subsoil are very satisfactory.

It is evident from the percentages of calcium carbonate present in the surface soil and subsoil that the land has been given liberal dressings of lime in the past.

Centre F.—Geological Formation—Midford Sands.

The soil of this plot is a sandy loam of a fairly easy working character.

Up to the present, it has not been possible to visit this plot for the purpose of taking soil samples, but samples of the surface soil and subsoil were taken by the grower and forwarded to us.

The results obtained in the mechanical analyses of the two samples are very interesting and suggestive, and it is felt that this soil should be examined at depths below 18 inches.

It will be seen that the soil is devoid of stones and that in the surface soil the only fraction present in any considerable amount is the fine sand fraction. In the subsoil, this fraction is again the predominating one, whilst the percentage of clay is practically twice as great as in the surface soil. When viewed under a microscope, the grains of fine sand are seen to consist of flat angular plates of a highly siliceous character.

The chemical analyses bring out the following points :

The amounts of organic matter present in the surface soil and subsoil are small.

The amounts of total potash are low in both samples, whilst the available potash is only moderate in the surface soil, and is low in the subsoil. The soil is well supplied with phosphates, and has, apparently, received heavy dressings of lime in the past.

Centre G.—Geological formation—Old Red Sandstone near junction with Wenlock Limestone.

The soil at this centre is on the light side, and works easily. Holes were dug on the plot to a depth of 3ft.—4ft., and an examination of the soil at the various depths in these holes showed that there was a sharp change in the soil texture at a depth of 18 inches from the surface. The soil below this depth contained numerous large pieces of sandstone, which appeared to indicate the presence of a sandstone bed below. There is a sandstone quarry at a short distance from this leaf scorch area, where the sandstone rock is seen to lie at only a small depth below the surface level.

The mechanical analyses of the surface soil and subsoil samples give results which are typical of the lighter soils of the Old Red Sandstone Formation, and give no indication of the soil being other than normal for this type. An examination of the soil below 18ins., however, showed that below this point the soil differed in character from the soil above. It contained a considerable quantity of large pieces of calcareous sandstone. The actual percentage of these present in a given sample was not determined as they were too large to allow of a sample being taken in the usual way. Samples of these stones and samples of the soil between the stones, were taken for laboratory tests. All the stones examined were found to contain a high proportion of calcium carbonate, and they probably

consisted largely of Wenlock Limestone. The mechanical analysis of the soil sample taken is given in the table. The texture is still typical of an Old Red Sandstone soil, but the sample was found to contain 12·82% of calcium carbonate.

The results of the chemical analyses of the surface soil and subsoil are typically those of an Old Red Sandstone soil.

The percentage of organic matter—7·46%—is usual for pastures on this type of soil (this plantation was an old pasture until a few years ago), the total potash is higher in the surface soil than in the subsoil, being fairly high in both, whilst the amounts of available potash are low in both samples. The percentages of total and available phosphoric acid are fairly good in the surface soil and are low in the subsoil.

The soil had been limed recently and had been given liberal dressings of manures, such as meat meal, slag, superphosphate, etc.

On this plot it is possible that the development of the roots of the trees might be restricted by the stony layer underlying the subsoil.

Centre H.—Geological Formation—Old Red Sandstone.

At this centre, the soils of two adjoining plantations were examined. In one of the plantations almost all the trees were affected with leaf scorch, whilst in the other none of the trees showed any signs of scorching.

The soils were identical in appearance, both being heavy loams belonging to the Old Red Sandstone system. Samples of the surface soil and subsoil were taken from each plot and mechanical and chemical analyses have been carried out on all the samples.

Sample from Leaf Scorch Plot.

The chief points brought out by the mechanical analysis of the surface soil are that the soil contains no stones, the amounts of fine gravel and coarse sand are very small, the middle fractions of the soil—fine sand, silt and fine silt—are present in large proportions, together comprising 75·86% of the soil, whilst the amount of clay present is below what one would expect it to be from observations made in the field.

The subsoil is similar in texture to the surface soil, but there is one difference which may be of great importance, viz., the amount of fine sand present in the subsoil is 40·37%, being approximately 14% above the amount of fine sand present in the surface soil. The amounts of silt, fine silt and clay in the surface soil are all greater than those present in the subsoil.

The chief points of note in the chemical analyses of the samples are as follows :—

The amounts of organic matter present in the samples are small.

The total potash in each sample is high, being slightly higher in the subsoil than in the surface soil.

The percentages of available potash are low in both the surface soil and in the subsoil.

Total phosphoric acid is present in fair quantity in the surface soil and is low in the subsoil.

The amounts of available phosphoric acid in both the surface soil and subsoil are high and the land has evidently received heavy dressings of phosphatic manures.

Calcium carbonate is present in small quantity in the surface soil and is absent from the subsoil.

The plot has not been limed of recent years, and is naturally deficient of lime.

Samples from No Leaf Scorch Plot.

The mechanical analysis of the surface soil of this plot shows the texture to be almost identical with that of the surface soil of the leaf scorch plot. When we examine the results obtained for the subsoil of this plot, however, it is seen that these results differ from those obtained for the subsoil of the leaf scorch plot. The amount of fine sand present in the subsoil of this plot is only 3% above the amount present in the surface soil, whilst the amounts of silt and fine silt are only slightly below those present in the surface soil and the amount of clay present is higher. The gradation shown between the textures of the surface soil and subsoil of this plot would appear to be fairly normal in character.

The results obtained in the chemical analyses of these samples are of the same order as those obtained for the samples from the leaf scorch plot, and the differences obtained, no doubt, are due to slight differences in the manurial treatments given to the plots.

Centre I.—Geological Formation—Old Red Sandstone.

The soil of this plot is very similar in appearance to the soil of the plots at Centre H, and this similarity of texture is brought out by a comparison of the mechanical analyses of the soils of the plots.

The mechanical analyses only of the surface soil and subsoil at this centre have been carried out.

A comparison of the results obtained for the surface soil and subsoil shows that the relation existing between these is very similar to that found in the case of the leaf scorch plot at Centre H, viz., the amount of fine sand present in the subsoil is 8.48% above the amount present in the surface soil, and the same relation exists between the amounts of silt and fine silt present in the two samples.

The amount of clay in the subsoil at Centre I is greater than the amount present in the surface soil, which is a point of difference from the leaf scorch soil at Centre H.

Centre J.—Geological Formation—New Red Sandstone, Keuper Marl.

A hole about 7ft. in depth was dug at this centre for the purpose of making observations on the water supply during the season. An examination of the soil on the sides of this hole showed that the soil was of great depth, and even down to a depth of 7ft, there was no marked change visible, the soil merely appearing to become gradually of a more clayey nature after a depth of 3ft. was reached. Apparently there could be no question of the leaf scorch occurring on this plot being due to lack of depth of soil.

The observations on the supply of water in the hole were not made very frequently owing to pressure of work, but on the two occasions on which the plot was visited by one of us, in June and September, there was no water in the hole on either occasion.

Soil samples were taken to a depth of 5 feet at this centre, and the results of the analyses of these are given in the table.

Although the soil of this plot belongs to a different geological formation from the soils at Centres H and I, the surface soil and subsoil of the plot are remarkably similar in texture to those soils. Here again, the dominant fractions of both surface soil and subsoil are fine sand, silt, and fine silt. The percentage of the last of these is remarkably high in the surface soil. The percentage of fine sand in the subsoil is 8% above the amount in the surface soil, and this percentage is almost maintained in the 2ft.—3ft. sample.

The percentages of the middle fractions present fall in the 3ft.—4ft. sample, where the percentage of clay rises sharply.

The results of the chemical analyses of the surface soil and subsoil samples may be summarised as follows :—

The percentage of organic matter present in the surface soil is higher than at Centre H, as the plantation is at present " down " to grass.

The amounts of total potash in the surface soil and subsoil are high, the amount in the former being higher than in the latter.

The amounts of available potash are low in both samples.

The total phosphoric acid is only moderate in amount in the surface soil, and is low in the subsoil.

The available phosphoric acid, like the total phosphoric acid, is moderate in amount in the surface soil, and in the subsoil it is very low.

The amounts of calcium carbonate present in the two samples are indicative of the applications of lime to the soil in the past. The samples taken below 18 inches were devoid of lime.

LEAF SCORCH SOILS—MECHANICAL ANALYSES.

	Centre A.	Centre B	Centre D	Centre E	Centre F	Centre G	Centre H *	Centre H †	Centre I	Centre J
Surface Soils :—										
Stones	26·0	14·5	Practically nil	22·8	Practically nil	8·8	nil.	nil	4·39	1·0
Moisture ..	1·76	1·33	2·37	2·76	1·96	1·90	2·40	2·47	2·75	3·27
Loss on Ignition	5·09	3·58	6·04	7·80	4·94	7·46	4·26	4·64	7·07	8·14
Fine Gravel ..	3·61	3·38	0·54	7·26	0·68	2·09	0·61	1·05	1·7	2·23
Coarse Sand ..	51·69	52·80	51·86	11·71	0·99	3·34	3·32	4·28	4·48	3·40
Fine Sand ..	17·09	..	16·80	19·04	59·67	36·10	26·41	26·58	31·98	21·78
Silt	5·24	..	6·49	13·03	9·34	19·90	26·53	25·95	22·21	22·12
Fine Silt ..	7·72	..	7·34	28·12	6·97	19·81	22·92	21·60	18·23	26·30
Clay	6·38	..	8·66	5·58	9·36	7·73	12·57	12·25	9·81	10·57
Subsoils :—										
Stones	30·0	16·3	nil	28·1	..	nil	nil	nil	4·4	4·5
Moisture ..	1·56	1·30	1·76	2·00	2·75	1·40	2·47	2·30	2·08	1·96
Loss on Ignition	3·55	3·58	3·30	4·58	4·08	3·76	3·12	3·42	4·31	2·92
Gravel	4·56	2·82	1·35	8·26	nil	4·66	0·46	0·47	1·34	3·57
Coarse Sand ..	52·92	52·50	51·14	11·71	0·38	4·00	1·21	3·09	5·08	3·73
Fine Sand ..	17·90	..	16·26	19·22	55·91	38·57	40·37	29·58	40·38	29·99
Silt	4·77	..	5·65	11·85	10·03	21·85	21·83	23·21	18·85	20·48
Fine Silt ..	6·95	..	7·16	30·52	8·18	16·85	18·75	21·53	15·49	23·50
Clay	6·84	..	12·32	11·07	17·50	7·90	10·79	15·21	11·59	12·64
2ft.—3ft. :—						‡				
Stones	24·7	15·2	nil	25·3		Num. cal. sandstones				2·0
Moisture ..	..	..	1·50	1·63		..				..
Loss on Ignition	..	..	2·84	3·28		..				..
Gravel	6·43	2·76	0·56	18·01		3·02				2·50
Coarse Sand ..	68·18	46·02	61·65	12·78		3·85				4·35
Fine Sand ..	13·24	..	11·69	17·04		33·99				28·28
Silt	2·94	..	3·29	9·41		19·17				17·97
Fine Silt ..	2·16	..	3·87	26·89		13·38				21·36
Clay	3·28	..	13·76	10·29		11·61				19·35

3ft.—4ft. :—										
Stones	48·0	26·7	nil	35·4						nil
Moisture ..	..	..	0·36	1·14						..
Loss on Ignition	..	..	2·41	3·52						..
Gravel	11·62	5·20	4·21	24·07						nil
Coarse Sand ..	59·36	29·32	68·33	20·32						1·39
Fine Sand ..	8·04	..	9·45	16·52						18·14
Silt	2·59	..	1·10	7·93						15·31
Fine Silt ..	3·19	..	1·01	19·09						20·78
Clay	9·89	..	0·90	7·23						37·01
4ft.—5ft. :—										
Stones	18·40	..	nil	..						nil
Moisture ..	..	..	2·92	..						..
Loss on Ignition	..	..	5·36	..						..
Gravel	5·32	..	0·44	..						nil
Coarse Sand ..	80·72	..	16·59	..						0·62
Fine Sand ..	3·23	..	7·36	..						15·12
Silt	0·72	..	10·07	..						17·42
Fine Silt ..	0·42	..	12·93	..						19·35
Clay	6·55	..	28·78	..						39·60

* Leaf Scorch Soil. † No Leaf Scorch. ‡ Between 18ins. and 4 ft. Numerous calcareous sandstones.

LEAF SCORCH SOILS—CHEMICAL ANALYSES.

	Centre A	Centre D	Centre E	Centre F	Centre G	Centre H *	Centre H †	Centre J
Surface Soils :—								
Moisture	1·76	2·37	2·76	1·96	1·90	2·40	2·47	3·27
Loss on Ignition ..	5·09	6·04	7·80	4·94	7·46	4·26	4·64	8·14
Potash (Total)	0·279	0·292	0·472	0·314	0·666	0·846	0·744	0·741
Potash (Available) ..	0·0181	0·0071	0·0117	0·0133	0·0106	0·0109	0·0129	0·0086
Phosphoric Acid (Total)	0·326	0·141	0·195	0·313	0·160	0·140	0·161	0·125
Phosphoric Acid(Available)	0·140	0·0116	0·0273	0·0916	0·0296	0·0599	0·0729	0·0144
Calcium Carbonate ..	0·270	0·138	2·51	5·52	0·366	0·120	0·060	1·026
Lime Requirement ..	nil	nil	nil	nil	nil	nil	nil	nil
Snbsoil :—		2nd Foot.						
Moisture	1·56	1·76	2·00	2·75	1·40	2·47	2·30	1·96
Loss on Ignition ..	3·55	3·30	4·58	4·08	3·76	3·12	3·42	2·92
Potash (Total)	0·243	0·140	0·520	0·437	0·586	0·853	0·807	0·698
Potash (Available) ..	0·0130	0·0046	0·0107	0·0098	0·0065	0·0058	0·0060	0·0058
Phosphoric Acid (Total)	0·238	0·108	0·167	0·214	0·0909	0·0661	0·0571	0·0668
PhosphoricAcid (Available)	0·101	0·0043	0·0264	0·0384	0·0057	0·0223	0·0101	0·0043
Calcium Carbonate ..	0·151	0·076	0·181	0·469	0·048	nil	0·037	0·053
Lime Requirement ..	nil	nil	nil	nil	nil	0·119	nil	nil
18*ins.*—4*ft* :—								
Calcium Carbonate ..					12·82			
Lime Requirement ..					nil			
3*ft.*—4*ft.* :—								
Calcium Carbonate ..		13·4						
Lime Requirement ..		nil						

* Leaf Scorch Soil. † No Leaf Scorch,

Summary of Results.

The noteworthy results of the analyses are summarised below, and for the purpose of bringing out more clearly the points of similarity between certain of the soils, the soils showing important features in common have been grouped together for discussion.

Centres A, B, C, D.—These are all light, sandy soils of the market garden type. The dominant fraction is coarse sand. In addition, the soils at Centres A, B and C contain high percentages of stones.

Chemically these soils contain poor potash supplies, and whilst the soil at Centre A at present contains a large supply of available phosphoric acid, the soil at Centre D is relatively deficient of this constituent.

The soils at Centres A, B and C are also naturally deficient in lime.

Centre E.—The dominant feature of this soil is its extremely stony character, and at a depth of 3ft.—4ft. the soil resembles a gravel pit.

The supply of potash is only moderate, whilst the supplies of phosphoric acid and lime in the surface soil and subsoil are good.

Centre F.—The chief characteristics of the texture of this soil are the high percentages of the fine sand fraction present in both the surface soil and subsoil, and the lack of stones, fine gravel and coarse sand in the soil. The percentage of clay in the subsoil is twice as great as in the surface soil.

Chemically the soil is lacking in organic matter, and the supply of potash is on the small side.

The percentages of phosphoric acid in both the surface soil and subsoil are high, whilst the soil contains ample supplies of lime.

Centre G.—The textures of the surface soil and subsoil are typical of the lighter soils of the Old Red Sandstone Formation. At a depth below 18 inches from the surface, the soil contains large quantities of large calcareous sandstones and it is possible that the rock lies at quite a short depth below this point.

The supplies of total phosphoric acid are moderate, though heavy dressings of this material have been supplied. The soil is poor in available potash, and while the surface soil and subsoil are poor in lime supplies, the soil below this subsoil contains large supplies of this substance.

Centres H, I, J.—The soils at these centres are very similar in texture. The mechanical analyses show them to consist largely of the middle fractions. The soil on which leaf scorch occurred at H, and the soils at I and J, all contain a much higher percentage of the fine sand fraction in the subsoil than in the surface soil. This characteristic is not shown to the same extent in the soil from which leaf scorch is absent at Centre H.

The textures of these soils are such that they are probably very liable to "pack," in which condition they would possibly greatly hinder healthy root development. It is possible that the presence of considerably higher amounts of fine sand in the subsoils than in the respective surface soils of these plots is indicative of a condition of packing of particles in the subsoils, resulting in the formation of a peculiar type of hard pan.

Chemically, the characteristics of these types of soils are their low contents of organic matter, their naturally large supplies of total potash, their small amounts of available potash, their poor supplies of phosphoric acid and their limeless natures.

Some of these characteristics have been altered by manuring and by other means.

Further Examples of Scorching.

A further instance of scorching associated with soil conditions may be referred to in some detail, since it differs in some respects from the preceding and, being at Long Ashton, has been close under observation and treatment. The land in question is now cultivated, but was down to grass until about 10 years ago. It is on a southern slope, and the depth of the soil is generally not more than from 1 to 2 feet, underlying being a bed of broken stone. A year after it was first cultivated it was planted with fruit, mainly apples, plums, gooseberries and red currants. The plums as a whole have grown well and show little scorch, but many of the apples, especially the weaker growing varieties, have failed to make much growth and show a form of leaf scorch every year. The same may be said of the gooseberries and currants which have not received special treatment. The form of scorch in this instance is not so much of the marginal and leaf tip variety as one irregularly distributed over the surface of the leaf, which generally is much undersized. Leaf discolouration begins soon after unfolding and production of new foliage and shoot growth almost ceases by midsummer. The appearance of the plants being strongly suggestive of defective nutrition, a number of them were given a heavy dose of mixed artificials (sulphate of potash, superphosphate and nitrate of soda in most instances), a moderate dressing of farmyard manure having failed to improve them materially. The response to the artificials was rapid and most striking. The treated plants have remained practically free from scorch and have made normal growth, aided only subsequently by occasional dressings of farmyard manure. One year after the application of artificials some of the treated and untreated bushes were lifted. The difference in root development was seen to be of a most striking character, those of the treated plants being many times as large as those of the

untreated, which showed hardly any signs of formation of new roots.

Other experiments on land adjoining showed that the application of potash salts in combination with nitrogenous and phosphatic fertilisers sufficed to cure scorching and cause growth, while the application of nitrogen and phosphate without potash failed to do so.

On another adjoining piece of land similarly situated, which was planted with gooseberries a year ago, a similar suggestive result has been observed. Running right through the plot is a strip some 10 to 20 feet wide, which has been subject for many winters to washings by the overflow of a small adjacent pond. The bushes on that strip made practically no growth last season and the foliage was badly scorched from Midsummer onwards. Those in the rest of the plot made very good growth considering the season. It should be mentioned that the plot had received no recent manure before planting and nothing was given subsequently except sulphate of ammonia, when rains came in the latter half of July. This, like the preceding, appears to be a case of scorching due to defective nutrition on the portion of the plot subject to the overflow of water.

The shallowness of the soil in these instances is believed to have intensified the trouble, for in dry seasons the scorch has been more marked than in wet. But nutritive rather than dry soil conditions must be held primarily responsible, because scorch occurred in both dry and wet summers, and manurial treatment succeeded in checking what moisture alone failed to prevent.

In this connection attention may be called to cases of the converse order, to which reference was made in last year's Report in the article on "Root Formation in Newly Planted Trees." A description of the behaviour of apple trees grown in water culture was given, which showed that under such conditions very poor root growth was made in spite of the presence of an adequate supply of nutrients and water, owing to defective aeration of the root system. The foliage was poor, individual leaves being much smaller than normal and very subject to scorch. Here then a combination of nutrients in abundant supply and water produced the same kind of result as the deficiency of those materials in the previous instances, and the determining factor was evidently lack of aeration at the root, resulting in poor root growth and the consequent starvation and relative drought within the tree.

The effect of malnutrition in another form in inducing scorch was observed in a series of experiments conducted with almond trees a few years back. These were started with the idea that if the tree could be induced to absorb a sufficient quantity of a toxic salt without too serious injury to itself, the amount thus taken up might be capable of checking the development of leaf curl by direct toxic action on the fungus producing that disease, *Exoascus deformans*.

The trees under treatment were grown in pots, to the soil in which different amounts of lithium carbonate were added. With the heavier dressings the trees were killed outright, but where smaller doses were applied they made some growth. The leaves in such cases, however, were more or less scorched according to the quantity of lithium carbonate used, and the scorch was generally quite characteristic of the marginal and tip type. It is unfortunate that no examination of the root system was made in these cases, its significance not being appreciated at the time. Whether the toxic salt acted by restricting root growth as a result of direct injury to the root tissues on absorption or by producing unhealthy conditions elsewhere within the tree, there can be no doubt as to its responsibility for the scorch.

A somewhat analagous case* has recently been recorded for potatoes after treatment with fertilisers containing borax.

Another type of scorch familiar probably to the majority of growers of gooseberries is that associated with the "Die-back" disease of that plant caused by the fungus *Sclerotinia fuckeliana*. An account of this disease has been given in Leaflet No. 234, published by the Board of Agriculture (1914, 2nd Edition), the accompanying plates of which show the general appearance of the scorch on the foliage particularly well. It was believed earlier that the scorched margins of the leaves were caused by the presence of the fungus in the leaf tissues at those parts, but that view is thought now to be erroneous. The scorching is the result of the presence of the fungus in the vascular tissues of the plant in the main stem or a branch well below the affected foliage. It is brought about by the interference thus caused with the supply of water to the leaves above that point. There comes a time in due course when the fungal growth has increased to such an extent that the supply is cut off more or less completely. That generally happens quite early in the growing season. The foliage then, instead of scorching, suddenly wilts. This is a particularly interesting case from the scorch point of view, as illustrating that it is the degree of interference with the water supply which determines whether a general leaf wilt or scorch only takes place. It is evident that a shortage of water in the leaf can result in the latter without involving the former.

It is difficult to say whether scorch in such cases is the end result of a purely local wilt, limited to a small portion of the surface of the leaf, or whether it occurs without the tissues affected passing through a stage corresponding to wilt. Lutmann's account of Tip Burn of the potato and other plants† rather supports the former idea, but in the case of leaves of fruit trees no preliminary wilting of the

*W. J. Morse: The Effect of Borax in Fertilisers. Maine Agricultural Experiment Station, Bulletin 288.

† Lutmann: Tip Burn of the Potato and other Plants. Vermont Agricultural Experiment Station, Bulletin 214.

parts concerned is visible to the naked eye. The conclusion of that author in the cases of scorch described in his paper is that it is due to excessive heat and sunshine, which cause inordinate transpiration from the parts directly affected and so bring about local wilting from which recovery is not made.

Scorch Production by Fires.—During the summer of 1921, a chance observation was made on the production of leaf scorch by the heat of a fire lighted in a plantation for the purpose of burning refuse.

The fire had been lighted between two standard apple trees. Some of the leaves of the tree on the side of the fire were exposed to sufficient heat to destroy them completely, whilst some were only slightly injured and others remained uninjured. It was noted that the damage done to the slightly injured leaves was entirely marginal, the damaged leaves being similar in appearance to the leaves of trees affected with leaf scorch. The damage done to the leaves of the tree on the windward side—which had not been exposed to such great heat as the tree on the leeward side—was almost entirely marginal.

It is deduced from this incident that, when the foliage of a tree is exposed to temperatures just sufficiently high to cause some injury to it, the marginal areas of the leaves are the first parts to suffer.

Before passing to a description of the experimental work at Long Ashton on this problem, reference may be made to two other forms of scorching which have been reported. In the one case Wilfarth and Wimmer have shown* that in manurial experiments on sugar beet, leaf scorch occurs when the plants are deprived of potash. The other instance is the well-known one of the potato, which shows a characteristic leaf curl accompanied by scorch when the plant is insufficiently supplied with that constituent (Quanjer †)

Experimental Work.

The object of all the experiments about to be described was to reproduce leaf scorch artificially under controlled conditions in order to discover the factors causing the disease.

Experiments on Broad Beans.

Water Culture Experiments on Broad Beans.

At the outset of the work one of the most likely factors to cause leaf scorch appeared to be the concentration of salts in the soil.

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* Wilfarth and Wimmer. Die Kennzeichen des Kalimangels an den Blattern der Pflanzen. *Zeitschrift fur Pflanzen-Krankheiten.* 1903.

† Quanjer. *Medederlingen van de Rijks Hoogere Land, Trein-en Roschbouw-school,* Deel x., p. 95.

This was tested by the growth of broad beans in appropriate culture solutions, that kind of plant being selected as especially suitable on account of its quick growth and known liability to scorch.

Experiment 1 consisted of growing beans with the following treatments :—

A Normal food solution. Control.
B1 „ „ „ concentrated 10 times.
B2 „ „ „ concentrated 50 times.
C1 Containing sodium chloride giving a concentration 20 times that of food solution.
C2 Containing sodium chloride giving a concentration 50 times that of food solution.
C3 Containing sodium chloride giving a concentration 100 times that of food solution.

Six plants were used for each treatment, these being grown to a convenient size in normal food solution until required. The solutions B1, B2, and C3, caused wilting in a few hours and a blackening of the roots. After a few hours, the plants in C3 solution were transferred to water, whilst B1 and B2, were allowed to stand overnight before being transferred. After five days the results of the experiment were as follows :—The control plants were quite normal. The B1 plants completely recovered although showing some blackening of the roots. The B2 plants showed the young unopened leaves untouched, the top leaves scorched at the tip, the lower leaves at the tips and between the veins. In some cases the lower leaves were completely killed. The C1 plants were normal; C2 showed slight blackening of roots and signs of scorch on one leaflet; C3 showed severe blackening of the roots, but no scorch. The results of this treatment, therefore, indicated that sudden changes from normal to 10 and 50 normal resulted in wilting, followed by scorching when the action was severe. The scorching produced, however, although somewhat similar in appearance, was not identical with that occurring naturally which developes without wilting of the foliage.

Experiment 2 with the same plants was as follows :—

A Series of the 1st Experiment remained as Control.
B1 Series which had been in water for a few days, treated with food solution twice the normal concentration.
C3 Which had been in water for a few days, treated with food solution three times the normal concentration.
C1 Which had been under continual treatment with salt solution was placed in water overnight and then in solution four times normal concentration.
C2 as C1, but placed in a food solution five times normal.

The results were not altogether regular, although scorch very generally developed. After 9 days, scorching at the margins was present in the 3, 4, and 5 normal solutions, but not in the 2 normal and control plants.

On the tenth day the control plants were put in a solution 6 times the normal, the twice normal plants in a solution 7 times the normal. Five days later, viz.: 15 days after the start of the experiment, the results were as follows:—

The 6 × normal plants showed slight signs of scorch in 3 plants (two plants one leaf each and one plant with lower leaves). The 7 × normal plants showed 4 plants slightly scorched, although the scorching was more definite than with the 1 normal plants. Of the 3 × normal plants 3 scorched and 3 remained uninjured. The 4 × normal plants also showed 3 scorched and 3 uninjured and similarly the 5 × normal plants also showed 3 sorched and 3 uninjured. The irregularity of these results suggests at least that the concentration of the food solution is not the factor producing scorch.

Treatment 4.—In this case plants were grown in normal food solution to which various toxic salts (·1 grm. per 1000 cc.), were added. Copper sulphate and mercuric chloride killed the plants, causing shrivelling up of stem and leaves in general.

Treatment 5.—Root pruning of plants in water culture resulted in young leaves becoming scorched.

Pot Experiments on Broad Beans.

Experiment 1.—The object of this experiment was to determine if a limitation of the water supply is a factor in the production of leaf scorch. Analysis of the subsoil in a certain number of scorch soils had shown that the percentage of gravel increased downwards, giving a soil with a bad uplifting capacity for water. The experiment was made on the hypothesis that scorching ought not to appear if the surface soil of scorched areas were kept well watered.

The method of making the experiment was as follows:—Four different samples of surface soil taken from leaf scorch areas in the fruit plantations, D, F, G, J, were used and a fifth artificial soil was made up from 50% coarse sand, and 50% Research Station soil. Eight pots of the soils D and F and 10 pots of G, J, and the artificial soil were used. All the pots were waxed before the beginning of the experiment to make them impervious to water.

During the initial stages of the experiment the plants were raised under glass in a greenhouse. When the plants were well started, however, the following differential treatments were commenced. In the case of each type of soil the pots were divided into two lots. Half were placed in a trench, the bottom of which consisted of a layer of sifted ashes and coarse sand resting on a layer of coarse

ashes, which layer rested on the normal soil. The layer of ashes was about 9 inches deep. Fine ashes and coarse sand were filled into the trench round the pots. The ashes and sand mixture in the trench was kept in a moist condition, and the plants in the trenched pots drew the whole of their water supply from the ashes mixture in the trench. The other half of the pots were placed alongside the trench and were watered from the top. The final results of the number of leaflets scorched expressed as average per pot was as follows :—

	Bottom watering.	*Top watering.*
	%	%
D	8·75	5·25
F	·25	2·75
G	1·	·4
J	3·8	1·2
Artificial	4·4	4·6
	18·2	14·2

As far as they go these figures show that there was 28% more scorch on the bottom watered plants than on the top watered ones. The difference was not so striking as expected, and the fact that the top watered plants produced quite a definite amount of scorch, showed that watering was not the limiting factor in the production of scorch in this case.

None of the scorching soils produced such good roots as the artificial, and the root development of beans in those pots watered from the bottom, was decidedly inferior to those watered from the top. There was distinctly more blackening of the roots on the J soil than on any other, and the top watered plants were worse than the bottom watered.

The amount of top growth made by the top watered plants was distinctly greater than that of the bottom watered, each series giving consistent results in this respect.

Experiment 2.—The object of this experiment was to find (1) if increasing the concentration of the soil solution tends to produce leaf scorch and (2) if bright sunlight and shade are factors in leaf scorch production.

Twenty-five waxed pots were filled with artificial soil (50% Research Station soil and 50% sand), and broad beans—3 per pot were grown in them. The pots were then divided into 5 series of 5 pots each. The first series was watered from the beginning with a normal nutrient solution, the second with one twice the normal concentration, the third with one three times, the fourth with one four times, and the fifth with one five times.

The initial stages of the experiment were carried out in the greenhouse and the plants were moved later to the following position.

(1) One pot from each series was placed under a glass shelter, open on the sides.

(2) Two pots from each series were placed in strong sunlight in a greenhouse.

(3) Two pots from each series were placed in the same greenhouse, but were shaded by muslin.

Watering with respective nutrient solutions was continued in all the pots.

The results for experiment 2 expressed as average per pot were as follows :—

	Brilliant light.	*Shaded.*	*Outside shelter.*
	%	%	%
Normal..	4·5	1·0	4·0
2 „	9·5	3·0	2·0
3 „	5·0	3·5	2·0
4 „	2·0	2·0	—
5 „	4·0	2·5	—
Totals	25·	12·	8·

From these figures it appears that brilliant sunlight is favourable for the production of scorch, especially if combined with a somewhat high temperature which obtains in a greenhouse. There was no correlation, however, between the amount of scorch and the concentration of the food solution.

Examination of the roots showed that increasing the concentration of the soil solution induced less root development, and increased the blackening of the roots in each series. The series grown in the shelter had greater root development and less blackening than that grown under shade conditions in the greenhouse, which series in turn stood in like measure with regard to the unshaded. With the highest concentration a small type of leaf was developed. The outdoor plants had the best top development.

Experiment 3.—The primary object of experiment 3 was to determine if feeding with an excessive amount of nitrogen promotes the development of leaf scorch. Variations of nitrogenous feeding, therefore, were given so as to combine other possible factors with this one, to see if any such combinations produced leaf scorch. Eight pots were used in series 1, 2, 3, and 4, and ten in series 5, half containing the 50% Research Station soil and 50% sand and half containing the 10% Research Station soil and 90% sand. The plants were grown in the greenhouse and were watered with a nutrient solution containing three times the normal amount of nitrogen. When the plants were about 6-12 inches high, the following treatments were commenced :

Treatment 1.—Plants placed in the glass shelter and the feeding with nutrient solution substituted by normal top watering with rain water.

Treatment 2.—Similar to Treatment 1, but the watering was done from the bottom by placing the pots in the ashes sand trench, as in experiment 3.

Treatment 3.—The feeding with nitrogenous solution was continued, but half the plants were placed in direct sunlight and half in the shaded portion of the greenhouse.

Treatment 4.—Of the eight pots of this series, four (two of each sort of soil), were watered with just sufficient water to prevent wilting. The remaining four received the same volume of liquid as the preceding four in the form of nitrogenous nutrient solution.

Treatment 5.—Ten pots (five of each sort of soil) were left in the shelter and the treatment with nitrogenous nutrient solution continued.

The results expressed as average scorched leaflets per pot were as follows :—

	Treatment.	50 : 50	90 : 10
1.	Top watering	5·5	2·7
2.	Bottom watering	4·0	3·5
3.	Unshaded	3·5	5·5
	Shaded	5·5	9·0
4.	Rain water to prevent wilting	8·0	6·0
	Nitrogen solution to prevent wilting	7·0	4·0
5.	Nitrogenous feeding continued	4·2	2·2

It is extremely difficult to gather any definite conclusion from these figures.

The root development was greater and less blackened in the case of the 50 : 50 soil than in the 90 : 10. The outdoor plants again showed the best roots with least blackening, the indoor shaded ones stood next and the indoor unshaded stood last of all.

Experiment 4.—One of the characteristics of trees suffering from leaf scorch is the feeble development of roots. The possibility that this might be due to bacterial action could not be ruled out and, therefore, some trials were made to see if scorch could be produced on leaf scorch soils after they had been sterilised.

The four types of scorch soil, as used in experiment 1, were used in this experiment also. The pots containing the soil were autoclaved at 15 lbs. pressure for 1 hour, and were subsequently watered with water in which normal station soil had been allowed to stand. Half the pots were watered from the top and half from the bottom, as in Experiment 1.

The results expressed as average scorched leaflets per pot were as follows :—

	Top watering.	*Bottom watering.*
D	19·0	9·0
F	8·0	5·0
G	1·5	2·5
J	5·0	2·0
	4) 33·5	4) 18·5
	8·4	4·6

From this it appears that scorch was, therefore, not eliminated by sterilisation.

Experiments on Apple Trees.

Experiments on Variations of Soil Moisture.

When the disease was first being investigated the idea was held that it could be produced by a gradual drying up of the soil. To test the view a number of apple trees were submitted to a drying process. They were planted in boxes of about one cubic foot capacity. In each case the weight of the tree, box and soil were ascertained and the percentage of soil moisture determined. The experiment was divided into two parts. In one the trees were kept at constant, but different, soil moistures; in the other the soils were wet to begin with and then gradually dried off. Once or twice a week the boxes were weighed and the proper amount of water added to bring the percentage up to the correct figure. At the same time notes of the appearance of the trees were made.

The experiment failed to produce any typical case of scorch, though in one or two cases of the more severe treatments the leaves showed some browning. The discolouration was, however, general rather than marginal. Where drying up was allowed to go on fairly far the leaves produced were generally rather small and of a yellowish green colour, but showed an inclination to scorch. The experiment seemed to indicate, therefore, that drought alone would not produce scorch, but that other factors must come into play as well.

Experience in the field goes to support this supposition. In 1921, during the pronounced drought, established standard trees in gardens could be found which were so deprived of water as to have reached the wilting point, and yet no sign of scorching was apparent. Under these conditions the drying was slow and gradual, in fact just those conditions which might have been expected *a priori* to have produced scorch.

Experiments on Root Injury.

During the period of bright hot weather, which persisted practically without a break over the period from the middle of June to the middle of July, 1921, experiments were carried out on two methods of injuring the roots of apple trees, whilst the trees were in full leaf, to ascertain whether severe injury to the roots at that period of the year and under weather conditions likely to promote leaf scorch would result in its production.

Several apple trees—varieties, Bramley's Seedling and King of the Pippins—all of which were either two or three years of age, and which were growing in soil in 10 inch plant pots were used in these experiments.

All the trees were in healthy condition before the treatments were carried out.

Series A.—Root Pruning Experiments.

Trees were treated at various dates as follows:—Some of the soil was removed from the tops of the pots so as to bare the points of the stem from which the main roots branched off. Varying numbers of these roots were completely severed near their points of origin, some of the root systems being treated very drastically. The bared roots were covered again with soil and the trees given normal waterings daily and left out in the open, exposed to the sun.

There was no leaf scorch developed on any of the trees as the result of this treatment.

Series B.—Root Drying Experiments.

In these experiments, the trees, together with the soil of the pots which adhered to their roots, were removed daily from their respective pots and placed in positions where they were exposed to the direct rays of the sun. They were left in these positions for periods varying from one to four hours and then replaced in the pots. In this manner the roots were gradually dried. No water was given during the treatment. The treatment was continued with each tree—usually over a period varying from 7–10 days—until the leaves began to show signs of leaf scorch, when the tree was allowed to remain in the pot and small quantities of water given daily to prevent the tree from dying. Under this treatment the trees developed typical leaf scorch, and if only a very small quantity of water was given the scorched leaves were gradually shed. When trees had developed leaf scorch fairly extensively they were dressed with a dung mulch and kept well watered with a complete nutrient solution. Under this treatment the trees developed a new set of foliage which was healthy and free from leaf scorch.

Manurial Experiments with Apple Trees Grown in Sand.—During the season of 1921, an experiment was commenced to discover the effect of omitting the various elements of plant food from the diets of apple trees grown in sand contained in 10 inch plant pots.

Towards the end of June, some of the trees began to develop leaf scorch, and the distribution of the scorching among the series appeared to be of such significance as to warrant the inclusion of the observations made in this report.

The details of the method of experiment, etc., followed are described fully in another paper,* so that it is only necessary at this point to refer broadly to the differential treatments given to the trees of the various series.

The trees of all the series were planted on February 25th, 1921. Previous to planting, all the root systems were treated in the Stringfellow method and after planting all the trees were pruned.

The variety used was Cox Orange Pippin and all the trees were said to be on Broadleaved Paradise stocks. There were eight differential manurial treatments given, *i.e.*, there were eight series, and each series consisted of five trees. The details of the manurial treatments given to the various series were as follows :—

Series A.—Received a complete nutrient solution.
„ B.— „ „ „ „ „ plus an extra amount of sodium sulphate.
„ C.—Nitrogen was omitted from the complete nutrient solution.
„ D.—Potash „ „ „ „ „ „ „
„ E.—Phosphoric acid „ „ „ „ „ „
„ F.—Calcium „ „ „ „ „ „ „
„ G.—Magnesium „ „ „ „ „ „
„ H.—Received rain water only.

Observations on the Foliage of the Trees.—Observations on the character of the foliage of the trees were made weekly during the growing season, but for the purpose of this paper it is sufficient to give an account of the observations made on two occasions, viz., July 6th and September 24th, as on July 6th, the distribution of leaf scorch on the trees was typical of its distribution during the mid-season and on September 24th, of the leaf scorch present during the latter half of the season.

Further, it should be noted that the presence of leaf scorch on the trees was observed for the first time during the season on June 20th.

Observations made on July 6th.

Series A.

Trees Nos. 1 and 4.—There was no leaf scorch present.

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* This Report. p. 42.

Trees No. 2.—A small amount of leaf scorch was present at the tips of leaves.

,, No. 3.—There was a medium amount of leaf scorch at the tips and on the margins of the leaves.

,, No. 5.—The leaves were all badly affected with leaf scorch.

Notes.—Nos. 2, 3, 4, were showing some yellowing of the leaves. No. 1 had started leaf growth very late and the leaves were small. The leaves of the trees in this series were generally well developed in size and were dark green in colour.

Series B.

Trees No. 1.—There was no scorch present. The leaves were small as in A1.

,, Nos. 2, 3, 4.—There was a fair amount of leaf scorch showing at the tips of the leaves.

,, No. 5.—The leaves showed bad leaf scorch at tips of the leaves and around the margins.

Notes.—The leaves of the trees in this series in general were very similar to those of the trees in Series A., both in colour, size and amount of leaf scorch present. Some of the leaves showed a little yellowing.

Series C.

There was no leaf scorch on any of the trees.

The leaves of the trees of this series were similar in size to those of Series A, but were lighter green in colour.

Series D.

Trees No. 1.—There was no leaf scorch present. The leaves were small as in A1.

Nos. —2, 3, 4, 5.—The leaves of all these trees were badly affected with leaf scorch.

Notes.—The leaves of the trees of this series previous to their becoming badly affected with leaf scorch were similar in size and colour to those of the trees in Series A, and had shown no signs of being in any way abnormal.

Series E.

Trees No. 1.—There was no leaf scorch present. The leaves were small as in A1.

,, Nos. 2, 4, 5.—There was no leaf scorch present.

,, No. 3.—The leaves showed a little leaf scorch at the tips.

Notes.—The leaves of this series appeared to be somewhat smaller than in Series A, and were slightly lighter green in colour. The leaves of Nos. 2, 3, 4, 5, showed signs of yellowing.

Series F.

Trees Nos. 2, 3, 4.—There was no leaf scorch present.

,, Nos. 1 and 5.—Showed a little leaf scorch at the tips and along the margins of the leaves.

Notes.—The leaves of the trees of this series were generally large and well developed. Nos. 1, 5, showed considerable yellowing of the leaves.

Series G.

Trees Nos. 1, 2, 3, 4, 5.—A small amount of leaf scorch, mostly at the tips of the leaves, was showing.

Notes.—The leaves of the trees appeared to be similar both in size and colour to those of the trees of Series A. The leaves of No. 1 tree were smaller than those of the other trees. Nos. 1, 2, 3, showed slight yellowing of the leaves.

Series H.

The leaves of the trees of this series were similar to those of Series C, being light green in colour and showing no leaf scorch whatsoever.

Summary of Observations on Leaf Scorch made on July 6th.

Series D.

The leaves of all the trees, with the exception of No. 1, showed severe leaf scorch. The trees of this series were affected with leaf scorch to a greater extent than those of any other series.

Series A, B, G.

The leaves in these series were affected to approximately the same extent. The amount of leaf scorch present was much less than in Series D.

Series E.

The amount of leaf scorch present in this series was slight. It was decidedly less than in Series A, B. G.

Series F.

Only one tree of this series showed signs of leaf scorch, and on this tree leaf scorch was only present at the tips of the leaves.

Series C, H.

There was no leaf scorch present in these series.

Observations made on September 24th.

Series A.

Trees Nos. 1, 2, 3, 4.—There was no leaf scorch present on these trees.

,, No. 5.—A small amount of leaf scorch was showing.

Notes.—The trees were still in full leaf. The leaves were of a normal green colour and showed no signs of falling.

Series B.

Trees No. 1.—There was no leaf scorch present.

,, Nos. 2, 3, 4, 5.—A small amount of leaf scorch was showing on these trees, mostly at the tips of the leaves.

Notes.—The leaves of the trees were similar in size and colour to those in Series A, and showed no signs of falling.

Series C.

Trees—There was no leaf scorch present on any of the trees.

Notes.—Nos. 2, 5, were completely defoliated.

,, Nos. 2, 4, were partly defoliated. The leaves remaining were pale green in colour.

,, No. 1 was in full leaf and the leaves were normally green.

Series D.

Trees No. 1.—The leaves showed slight leaf scorch—generally at the tips.

,, Nos. 2, 3, 4, 5.—The leaves of all these trees were badly affected with leaf scorch.

Notes.—The colour of the leaves where leaf scorch was not present was similar to those of Series A. Some of the leaves had fallen.

Series E.

Trees Nos. 1, 2, 4, 5.—There was no leaf scorch present.

,, No. 3.—The leaves showed slight leaf scorch mostly at tips. The leaves were smaller than in series A, and were still green. Some leaves had fallen.

Scries F.

Trees Nos. 2, 4.—There was no leaf scorch present.

„ Nos. 1, 3, 5.—The leaves were showing a small amount of leaf scorch.

Notes.—The leaves on all the trees were large and well developed. Those on No. 2 were turning yellow.

Series G.

Trees Nos. 1, 2, 3.—The leaves were showing slight leaf scorch.

„ Nos. 4, 5.—The leaves of these trees were badly affected with leaf scorch, and were similar in appearance to those of the badly affected trees of Series D.

Notes.—The leaves of all the trees had commenced to fall. Nos. 4, 5, had lost considerable proportions of their foliage and the remaining leaves were in very poor condition. By October 10th, the leaves of all the trees of this series were very badly affected with leaf scorch.

Series H.

Trees.—There was no leaf scorch on any of the trees.

„ No. 1.—Was still in full leaf and the leaves were green in colour.

„ Nos. 2, 3, 4, 5.—These trees were partly defoliated and the leaves remaining showed considerable yellowing

Summary of Observations on Leaf Scorch made on September 24th.

Series D.

The trees of this series were affected with leaf scorch to a much greater extent than the trees of any other series.

Series G.

Two trees of this series were affected with leaf scorch to a similar degree to the worst trees in Series D. The amount of leaf scorch present in this series was second in amount to that in Series D.

Series A, B, F.

The amounts of leaf scorch present in these series were very similar and were only small. The amount in Series B., was slightly greater than in Series F, and the amount in F, slightly greater than in A.

Series E.

Only one tree of this series showed any leaf scorch and the amount present was very small. The total amount of leaf scorch present was less than in Series A.

Series C, H.

As on July 6th there was no leaf scorch present on the trees of these series.

Observations on the Root Systems of the Trees.

In order to ascertain whether the varying amounts of leaf scorch observed on the individual trees throughout the season showed any correlation with the development of their root systems, the trees were removed from the pots on December 10th, after all the leaves had fallen and the root systems examined.

The observations made are recorded below.

Series A.

Trees No. 1.—The root system of this tree appeared to differ in type from the remainder of the trees. It is probably of the free stock type, whilst the others are of the Paradise stock type. The root system of No. 1 was much smaller than the root systems of the others.

,, Nos. 2, 3, 5.—The root systems were well developed and showed fair amounts of recent growth.

,, No. 4.—The root system was similar to those of Nos. 2, 3, 5, but was not so well developed.

Series B.

Trees No. 1.—The root system was similar to A 1.

,, Nos. 2, 3, 4, 5.—The root systems were good and similar to A 2, 3, 4.

Series C.

Tree No. 1.—The root system was similar to A 1.

,, Nos. 2, 3, 4, 5.—The root systems were all well developed and were very similar in size to A 2, etc. They differed from these in the fact that the root fibre was finer and there was practically no recent growth to be seen.

Series D.

Trees No. 1.—The root system was similar to A 1.

,, Nos. 2, 3, 4, 5.—The root systems were all smaller in amount than the root systems of C 2, 3, 4, 5. The root fibre was similar in appearance to that of Series A, being coarser than in Series C, and the roots showed more recent growth than those of the trees of that series.

Series E.

Trees No. 1.—The root system was similar to A 1.

,, Nos. 2, 3, 4, 5.—The root systems were similar in amount to A 2, etc. The fibre was coarse and the roots appeared to be healthier in colour than in any other series. The amount of recent growth was greater than for Series A.

Series F.

The amounts of root formed by the trees of this series were less than in Series A, and the root fibre was finer than in this latter series. The amount of recent growth made was greater in this series than in any other.

Series G.

Trees No. 4.—The root system was similar to A 1.

,, No. 5.—The stock appeared to be weaker than those of the other trees, but was similar in type.

,, Nos. 1, 2, 3.—The roots of these were well developed, being similar in amount and in type of fibre to those of Series A. There was a fair amount of recent growth.

Notes.—The roots of this series were blacker in colour than those of the other series, which might be a sign of unhealthy root conditions.

Series H.

Trees No. 1.—The root system was similar to A.1.

Notes.—The root systems of this series were similar in amount and type of fibre to those of Series C. The amount of recent root growth was greater than in Series C, whilst the colour of the roots in Series C, was slightly darker than in Series H.

Summary of Observations on the Root Systems made on December 10th.

Series D.

The amounts of root formed during the season by the trees of this series were less than in any other series. The root fibre was of a similar degree of coarseness to that of Series A.

The amount of recent growth made was greater than in Series C, H.

Series C, H.

The root systems in these two series were similar in amount and in type of fibre. The amounts in each series were almost equal to those of the trees in Series A, but the fibre was much finer. In Series C, there was practically no recent growth to be seen, whilst in H, there had been a certain amount of new growth made.

Series F.

The amounts of root made by the trees were less than in Series A. The type of fibre was similar to that of Series C, H. The amount of recent growth made was greater than in any other series.

Series G, E, A, B.

The amounts of root and the types of fibre made by the trees of these series were similar.

In Series E, the roots looked healthier than in any other series, and the amount of recent growth made was second to that made in Series F.

The roots in Series A and B were practically identical in all respects.

The roots in Series G were blacker than those of the other series and probably indicated unhealthy conditions.

Note.—Trees A 1, B 1, C 1, D 1, G 4, H 1, appeared to be on root stocks of the free stock type, whilst all the remaining trees were on stocks of the Paradise stock type.

Production of Scorch by Stem Ringing.

Those who have observed the effects of ringing of fruit trees will have noticed colour changes in the leaf and premature defoliation of the parts of the tree above the ring. In the case of bush apples ringed in spring, for example, the leaves concerned gradually became a yellowish shade of green and took on autumn tints at the end of the summer, while the foliage on parts of the trees unaffected by the ring behaved normally. Nothing in the way of a definite scorch follows ringing as a rule under Long Ashton conditions, and there is no ground for regarding the colour change referred to as being related to scorching. It appears to be simply a case of accelerated autumn effect.

On a few occasions, however, indications of undoubted scorch have developed within a relatively short time after ringing. One of the most striking cases, which can be quoted as an example, was that of a Jefferson fan-trained plum tree, growing against a wall of south-west aspect. It was ringed in the usual manner by the removal of a strip of bark as deep as the cambium layer. In this particular case the ring was not quite complete, but extended about seven-eighths of the way round the trunk. The leaves developed the regular yellowish tint in early midsummer and soon afterwards during a spell of hot dry summer weather suddenly scorched strongly. They became besides decidedly curled inwards. The trouble was confined to leaves exposed to full sun. Those more or less completely shaded remained green, uncurled and unscorched to the end and persistent on the tree rather later in the autumn.

The type of scorch in these cases is similar in general character to that occurring on scorching soils and its production is clearly a result of the ringing treatment, which, however, is only effective in certain instances and must, therefore, be then associated with other predisposing conditions.

Experiments on Interference with Water Supply to the Leaf.

When during the course of last summer the cumulative evidence pointed more and more strongly to the water relations of the leaf as the ultimate factor to reckon with in connection with scorch, a number of attempts were made to induce scorch directly by interference with the vascular tissues supplying the leaf with water. The method adopted was the severance of the veins by the point of a sharp razor or scalpel, injury of the surrounding tissues being avoided as far as possible. In some cases the mid-rib only was severed, this being done at various points of its course along the leaf-blade in different leaves. In other instances lateral veins in various positions were cut and in yet other leaves the marginal veins were treated on similar lines. The result was unexpected. The treated leaves suffered no observable ill-effect whatsoever. Neither scorch nor wilt appeared and for weeks afterwards the leaves remained on the shoots apparently functioning normally. Ultimately wind brought the test to a conclusion by causing tearing of the leaf blades, beginning in the region of the cuts.

From this it would seem that the leaf tissues are remarkably well equipped for rapid conduction of water from one point to another and that the channel of supply to a given area is not necessarily along a definite route of vascular strands.

Failure to produce scorch by these means may possibly have been due to the time of year when they were tried. Scorch effects seem to be largely dependent upon atmospheric conditions favouring very rapid transpiration. The end of July and early August, when the trials were made, was a period marked at Long Ashton by a temporary break in the drought which prevailed over the summer as a whole. In addition it is questionable if normally at that season of the year in the West of England the amount of transpiration approaches that for June and early July, when scorch is most prevalent.

A more drastic method of restricting the water supply to the leaf was subsequently tested, a cut being made across the base of pulvinus through the vascular bundles supplying the leaf. Rapid change followed this treatment, the whole leaf surface becoming discoloured and leaf-fall taking place within the course of a few days. The discoloration was of a brownish character, but not quite typical of

scorch. Until further experiments are made earlier in the summer it would be well to suspend judgment as to whether or not this represents an extreme case of scorch.

Discussion of Results.

From the foregoing account of observations and experimental work it appears that the cases of leaf scorch recorded fall into a number of more or less distinct groups. With those directly caused by access of toxic substances to the leaf tissues from the surface of the leaf, under which head are included the salt spray injury referred to in Boodle's paper and the numerous instances of spray fluid injury familiar to all growers, the present article is not concerned, since they obviously stand apart from the form under investigation. The remainder cannot be so definitely dismissed from consideration and may be classed broadly as follows :—(*a*) those in which scorching is associated with soil conditions, (b) those in which scorching is a direct result of wind, (*c*) those caused by the action of heat on the leaf, and (*d*) those resulting from injury to the vascular system of the tree. In no case among those included under these classes is there any question of a foliage parasite being the immediate cause of the death of the cells of the leaf tissues in the scorched areas. Death without doubt results from unhealthy internal conditions within the cell, brought about in some manner other than direct attack by a parasite. To arrive at conclusions as to the manner in which these unhealthy conditions are produced it is necessary to discuss separately the evidence available for each of the groups indicated.

The first group, in which soil influence obviously comes into play, comprises cases which show clearly that this influence is of a varied character. The main feature which they have in common is a relatively poorly developed or defective root system of the affected plant. In this group scorching certainly is associated with inadequate root development. A soil, therefore, has scorching tendencies when it cannot sustain regularly the amount of root growth required by the plant. The cases investigated furnish illustrations of different methods of soil action in this respect. These may be referred to briefly in turn.

It was shown in the manurial experiments with apple trees in pots that, where potash salts were omitted from the food solution, the root development of the trees was poor and severe scorching was present. The analyses of the scorching soil samples A-J, also showed that the supplies of available potash in these soils were low. Further, the results with trees grown in soil to which a toxic substance, such as lithium carbonate, etc., had been added, show that scorching can be caused by the presence of such compounds

in the soil when in quantity insufficient to produce immediate death. In all there instances the characteristic tip and marginal scorch on leaves of normal size has been observed. In other cases the plant makes very little growth and the leaves are much undersized. From the opening of the buds the foliage looks unhealthy and scorching is irregularly distributed over the leaf surface instead of being typically marginal. In some of these manurial treatment with potash salts has resulted in normal healthy growth and it is possible that all may be due to potash deficiency alone, notwithstanding that a lack of nitrogen may occur as well.

The mechanical character of the soil also seems in some cases to be capable of producing scorching. It is known that healthy root growth requires adequate soil aeration and the reference to the undersized and scorched leaf production shown by trees grown in water culture shows the association of that feature with defective root aeration. There is little doubt that in certain cases cited above the preponderance of the finer fractions indicates a badly aerated soil and correspondingly poor root development, the upper layers possibly being too dense sometimes and the tendency towards packing and the formation of a pan being marked in other instances.

The soils in other of the cases examined show poor water-lifting or holding capacity and it may certainly be assumed that during dry periods free root action and growth in them is restricted owing to inadequate water supply.

There is at least one further possibility in which the soil may be involved and that may be particularly noted, since it has been strongly favoured by the grower concerned in one of the cases described in detail above. It is that during the early part of the growing season root damage may occur as the result of an attack by an insect or fungoid pest present and active in the soil at that particular season. Provided that the damage were extensive enough it is possible and even probable that scorching would ensue, but there is practically no evidence in favour of this suggestion and there are at least two important results tending to negative it. To be effective the hypothetical pest would presumably be much in evidence at the critical season; yet no sign of any suspicious organism has been found in spite of careful search and the only suggestive circumstance discovered has been a series of superficial scars on the surfaces of certain roots sent in for examination. The cause could not be traced, but the extent of the trouble was certainly far too slight for it to be held responsible for the scorching observed on the foliage of the affected trees. On the other side, the facts (a) that scorching soils retain their scorching qualities after sterilisation by heat, as shown by the bean experiments, and (b) that severance of a considerable proportion of the main root system did not induce

scorching in pot apple trees thus treated, seem decisive and, while not necessarily disproving the root damage by pest hypothesis, show that very positive evidence should be furnished before it could be justifiably accepted.

The second group of cases, those in which scorching is directly a wind effect, seems to be composed of two distinct sets. The one is dealt with in some detail in Boodle's paper and is, according to that author, to be regarded as caused by excessive transpiration, resulting from the play of drying winds upon the foliage. The other, according to the observations of Barker and Gimingham, shows wind action in a somewhat less direct manner, the leaf tissues being affected locally by the chafing of one leaf upon another when stirred by breezes. Whether unhealthy cell conditions are set up through such mechanical irritation, or whether the cuticular surface is weakened and excessive transpiration follows on that account, has not been positively settled.

The third class of case, in which heat appears to play the primary part, is particularly well illustrated by the example quoted where scorch appeared on orchard trees exposed to hot air coming from a neighbouring fire. Instances of scorching of foliage under glass and of spot scorching after watering in hot sun are probably rightly regarded as "burns" pure and simple.

In the fourth group of cases interference with the vascular system of the tree is regarded as the cause of trouble. The example given of scorching following bark-ringing in the case of a plum tree furnishes an illustration of this type and the marginal scorch frequently seen on the foliage of trees attacked by a vascular parasite, *e.g.*, on gooseberries in the early stages of an attack of the "die-back" fungus, *Sclerotinia fuckeliana*, also falls under the same head.

This brief summary will suffice to show the varied character of the conditions which induce scorching. The question naturally arises as to whether the death of the affected parts of the leaves is due in all these instances to the same immediate cause, or whether the latter is variable as well as the predisposing conditions. Boodle's review of previous workers' opinions indicates a general inclination to regard scorch as a case of death due to unhealthy cell conditions produced by dessication resulting from excessive transpiration. The tendency of the leaves in most cases to show the first signs of scorch at the tips and margins or, in other words, in those regions most remote from the main vascular supply, has been regarded as strongly favouring that view. This aspect, therefore, calls for first consideration.

At the outset it should be explained that the term "excessive transpiration" will be used here in a relative and not absolute sense. Whether the amount of transpiration is excessive or not in this connection obviously depends as much upon the quantity of water reaching the cell as upon that given off by it.

That loss of water by transpiration is intimately connected with scorching seems likely, since generally in all the types of cases recorded the trouble appears most markedly in hot sunny and dry spells of weather; but this point must not be pressed too far, since other forms of activity on the part of the plant may also be intensified under those conditions. Moreover, the facts that scorching occurs in wet seasons and also on the foliage of trees grown in water culture suffice to demonstrate that the matter is not a simple one of amount of transpiration alone.

The forms of scorching brought about by soil influence up to a point are in accord with the excessive transpiration hypothesis. Thus the relatively poor root formation characteristic of such cases is presumably associated with a relatively low intake of water and the periods during the growing season when atmospheric conditions favour rapid transpiration are also those when the soil has least water available for the tree. One can imagine, therefore, a tendency towards a lack of water in the most affected parts of the foliage. On the other hand, whatever might be the case with a newly planted tree, it would be expected that an established tree would so balance shoot and root production that the leaf surface produced would not be greater than the existing root system was capable of maintaining. Although on typical scorching soils scorch is often observed to grow more severe as the tree ages, yet in the extreme cases after several years the leaves produced are so small that they do not scorch. Here apparently the balance between root and leaves is restored. Then again the production of a second crop of leaves which escape scorch, a common occurrence on many scorching soils, is at first sight not easy to account for if the root system remains inadequate. These difficulties are emphasized by the results of some of the earlier experiments with trees in pots. In those, as already described, when from the beginning of the growing season supplies of water at the root were kept low and the trees themselves were placed under glass in a relatively dry atmosphere so as to secure optimum conditions for a high initial rate of transpiration, the foliage from the start was relatively poorly developed, quite in keeping with the deficient water supply at the root, and no typical scorch was produced. In other words, the tree adjusted its leaf surface to its root system and available water supply. By keeping the latter very low wilting of the leaves in hot weather ensued, but never any typical well-developed scorch.

Some light may be thrown upon this aspect of the question if the results described in a later article in this Report, that dealing with Studies on Root Development, are considered. The suggestions here made are to be regarded as purely tentative, since they have arisen as the outcome of two series of investigations conducted during the past season which at the outset were not thought to be

in any way related and no opportunity for testing them can occur before the growing season of 1922. In the article referred to, it is shown that apparently root growth varies considerably in rate at different periods of the growing season. For a short time at the beginning of the season it is active ; then, while shoot growth is continuing relatively rapidly, it becomes markedly slowed down ; and finally, as shoot growth slackens, it revives and remains active for the remainder of the growing season. From the point of view of leaf scorch it is significant that, except for the earliest period of growth at the start of the season, shoot and root growth do not correspond in pace. The observed facts seem to indicate that, while this initial growth on the part of both shoot and root is dependent primarily on reserves stored in the tree from the previous season's activities, after their exhaustion root growth is dependent on elaborated food passed down from the aerial portion of the tree. So long as the growth of the shoots is favoured by general conditions, they, being nearest the centres of production of food, viz., the leaves, are able to draw first on the available supply and in consequence restrict for the time being new root development on that account. For a time, therefore, comparatively early in the growing season, shoot growth tends to outstrip root growth. In due course a balance is reached, because the inferior root development must by degrees react on the shoots, tending to retard the further growth of the latter owing to the proportionately smaller amounts of water and salts which can be taken up from the soil. While this balance is being stuck, however, there must be a tendency for a shortage of water supply to the shoots, especially if atmospheric conditions happen during that time to favour a high transpiration rate, and drought lowers the content of water in the soil. The leaves as a part of the shoot system may, therefore, be temporarily short of water, a condition already indicated as leading to scorching. The cases of early summer scorching typical of certain soils may thus be accounted for. It remains to be considered how the affected trees can produce subsequently a second crop of leaves free from the trouble. Since scorching automatically reduces the amount of transpiring leaf surface, the adjustment of balance between leaf and shoot should be aided by scorch. Once this balance is arrived at, there seems no reason why normal shoot and leaf production should not be renewed. As the full new crop of foliage is developed in such cases during the second half of the growing season, by the time the total leaf surface is formed the atmospheric conditions normally no longer favour a high transpiration rate, and the risk of scorching has passed or at least is minimised. Rate of shoot growth also at that season has naturally slackened greatly and accordingly the tree is able to build up for the ensuing year a reserve of food to start the new season's growth from the

activities of the second leaf crop. On that account the earliest shoot and leaf growth of the season need not present any markedly abnormal features or obvious signs of ill-effect from the scorch attack of the previous year, this notwithstanding that, compared with an unaffected tree, the total growth for the whole season may be materially lessened consequent on the inevitable check to shoot growth which must occur if scorching is severe and followed by complete or partial defoliation. In course of time the tree subject to scorch will naturally be materially weakened and signs of the drain on its constitution will become increasingly obvious.

The cases of scorch due to wind action accord with the water deficiency hypothesis, including those cited by Barker and Gimingham. The rate of loss of weight of leaves which had been exposed to chafing caused by wind having been proved to be materially greater than that for untouched leaves is a fact which certainly suggests that too rapid loss of water is associated with the scorching which ultimately developes in the former instance. Wind scorch, it will be noted, does not necessarily involve an inadequate water supply from the roots. The latter may be in perfect working condition; the leaf alone may be in fault, through being unable to accommodate itself properly to the high rate of transpiration induced by the atmospheric conditions.

Something of the same kind may hold for the cases of heat scorch. Failure of accommodation by the leaf to sudden calls resulting from temporary high temperatures, is an explanation which fits the observed facts better than one which suggests a general deficiency in water supply within the plant, although even here also the rate of transpiration factor almost certainly comes in. Whether heat scorch is really a "burn" and, if so, whether there is any essential difference between "burn" and "scorch," are questions which will be considered presently.

The last group of cases, those connected with interference with the vascular tissues of the plant, naturally are, under a hypothesis involving interference with the water supply to the leaf, readily accounted for in all instances where the interference extends to the xylem portion of the vascular tissues. Where only the phloem is obstructed or severed, as in the case of scorch following ringing, the explanation does not appear so obvious. It is true that there is some loss of water from the exposed vascular system at the ring, but that does not seem sufficient to cause scorch in itself, otherwise ringing should normally be followed by scorching: and this is not the case. Although the water factor probably comes in here also, the matter seems more complex than one of mere interference with water supply to the leaf.

We reach, therefore, the conclusion that excessive transpiration or, possibly more accurately, the water relations of the leaf tissues

are apparently involved in all the cases of scorch referred to, but at the same time the trouble is not caused solely by a deficiency in the quantity of water supplied to the leaf. Lack of water alone results in wilting and the leaf may recover without any trace of scorch when the water supply is readjusted to requirements. Exposure to heat, *e.g.*, bright sunshine in the height of summer, or to strongly drying winds inducing very rapid transpiration, appears to be required to intensify the effects of a defective water supply before vital changes within the affected cells proceed so far that death results and a typical scorch is produced. As to the immediate cause of death the present position of knowledge does not justify any positive answer and possibly it may vary in individual cases. It has been suggested by different authorities that (*a*) it may be due simply to conditions of extreme dessication unduly prolonged, and (*b*) it may result from a toxic concentration of salts, or other substances within the cell caused by too great a loss of water. In either case the osmotic properties of the cells themselves and of the adjacent tissues become points of importance, and about them there is at present little precise knowledge available. There is a third possibility, which we suggest as worthy of examination and which so far as we are aware has not hitherto been considered. It is that death is caused by the inability of the cell to regulate its temperature within vital limits. There must be occasions when leaves of growing plants, especially in the Tropics or under glass, are exposed to sun heat sufficient in itself to be toxic, unless the cells possess means of regulating their own temperature. Since a healthy plant survives such exposure uninjured, it follows that cell temperature can be adjusted by it as required. The obvious methods of adjustment which suggest themselves are those of increased chemical activity and of increased transpiration, either of which would result in a lowering of temperature brought about by the heat absorbed in the operations. Shortage of water supply to the cell has already been pointed out as a feature of scorching ; hence it appears a plausible suggestion that cell death results from an inability to transpire sufficiently rapidly to keep the temperature within vital limits.

While the foregoing discussion demonstrates that at present an attempt to explain why leaves scorch involves much that is still speculative, this investigation has on the practical side a more definite and satisfactory result to show. The primary intention was to find, if possible, a method of prevention of leaf scorch on soils subject to the trouble, and it may be claimed that, although complete success may not be practicable in all cases, much has been learnt which encourages the hope of a considerable degree of control in many instances.

There are three factors which stand out most clearly, viz., potash

effect, the influence of grass and rootstock action. The correlation which has been noted between the amount of potash supply, root growth and the degree of leaf scorch, points very definitely towards the liberal application of potash manures as a remedial measure, unless it is known that the soil in question has already an abundant supply of available potash.

As regards grass influence the facts that scorch is rarely recorded for trees growing in grass and that in the case of one of the first scorching soils examined, the trees on which showed the trouble to a pronounced degree, the owner eventually decided to grass the plantation down, since when scorch is reported to be mitigated, suggest very strongly that growth of a cover-crop of grass is likely to be very effective in reducing scorch or causing its complete disappearance. The manner in which grass may act is a question which involves a lengthy discussion and no conclusive decision could be arrived at, since evidence not yet available is required. This it is hoped to secure from further investigation and further consideration of the point is best left over until such additional information is acquired.

After what has been shown as to the general association of a relatively poor root system with leaf scorch and the importance of active root growth, it follows that for soils with a tendency towards scorch only trees worked on free-growing types of rootstock should be planted. In addition, cultural operations tending to encourage active root growth and manurial treatment with the same object are obviously likely to lead to greater resistance to scorch.

In view of the apparent importance of restricting as far as possible the loss of water by trees on scorching soils, nitrogenous manuring should be conducted with discretion. While trees dwarfed by continued scorch effect may need nitrogen as well as potash to bring about renewed healthy growth, heavy nitrogenous dressings must tend to the production of a dangerously large leaf surface. It may well prove that it is better to withhold nitrogen altogether until improvement by potash treatment alone has been secured.

The data already obtained relating to the chemical and physical composition of scorching soils suggest that, when more information in this direction has been accumulated, it may be possible to predict with a fair degree of certainty the liability of any given soil to scorch. The importance of this point in preventing the grower from planting on unsuitable soils is obvious.

Wind scorch obviously is most easily avoided by refraining from planting in wind-swept situations. It this is at times unavoidable, the establishment of windbreaks should lessen the trouble.

The other forms of scorch are more special cases and in general largely beyond the grower's control, where fruit culture is concerned.

A NEW METHOD OF SULPHUR FUMIGATION.

By B. T. P. Barker and T. Wallace.

The Annual Report of the Station for 1919 contains an account of the investigations in progress on the fungicidal action of sulphur so far as they had proceeded to that time. They have since been continued so far as pressure of other work permitted, attention being largely directed towards the estimation of the minute amounts of sulphur which can render an atmosphere toxic to various fungi when discharged into it by suitable methods of vaporisation. This work has involved attempts to discover a method of chemical analysis delicate enough to determine quantitatively traces of the substance when present in a treated atmosphere to the extent of something less than one part in a million. It has also entailed an examination of various methods by which sulphur can be vaporised in a form which is active fungicidally. This note is concerned with the latter problem.

From the earlier results of the investigation it was evident that the toxicity of a treated atmosphere depends upon the presence of sulphur in the form of minute particles. These particles vary considerably in size, the larger ones being probably aggregates of others so small that under the highest powers of magnification they are barely visible to the eye, while the latter in turn may be aggregates of still smaller forms. An atmosphere charged with such particles possesses fungicidal properties towards fungi which are susceptible to the action of sulphur, but such action may be removed from it by passing it through a dry cellulose filter, or even at times through a bent tube of narrow bore, thereby demonstrating that the effective sulphur is present not in the form of vapour but of particles of filtrable size. When air containing particulate sulphur is passed into water a suspension of colloidal sulphur is obtained. Sulphur distributed to growing plants through the atmosphere in this particulate form not only furnishes a much more complete superficial covering than can be secured by the older method of dusting or dry-spraying with flowers of sulphur, but also possesses a remarkable power of adhesion, withstanding the action of heavy rains or jets of water of considerable force.

The production of particulate sulphur for atmospheric distribution has long been utilised in greenhouse cultural work by horticulturists, who, in the past, generally produced it by coating the hot water pipes of the houses with a paste of sulphur. A still simpler method has been adopted with some success, this consisting merely in placing shallow pans of flowers of sulphur at various points of the house. Both of these methods, while admittedly useful, lack the element of control which is obviously to be desired in any system for combating disease. An improvement in this respect is offered by the so-called " vaporisation " method, the principle of which is utilised in such forms of fumigator as Campbell's " Sulphur vaporiser." It consists in essentials of boiling sulphur under such conditions that the vapour evolved condenses to a dense cloud of solid particles in a very fine state of division, the risk of ignition of which is reduced by an arrangement for keeping the source of heat out of reach. By this device a regulated amount of sulphur can be discharged into the atmosphere of the house, but careful application is necessary since the sulphur in the course of the process has to be raised to a temperature higher than that of its ignition point and there is always, therefore, a danger of its burning and consequent conversion to sulphur dioxide with injurious results to growing plants in the house. These drawbacks have been overcome during the course of the investigation at Long Ashton by a modification of the latter method, suggested by Mr. F. Tutin, and worked out by Mr. W. Camps, our research assistant. He has found that by passing a current of air over the surface of molten sulphur at temperatures only a few degrees above its melting point and well below the ignition point an abundant cloud of sulphur in the particulate condition is produced. The melting point of sulphur is about 115° C., its ignition point in air about 260°C., and its boiling point about 444°C. The most satisfactory temperatures of the molten sulphur for air-blast treatment appear to lie between 170°C. and 230°C. All risks of ignition are thus eliminated and any house under treatment can be charged with any desired amount of sulphur with safety. An improvement in the yield of particulate sulphur is effected if the current of air is passed through the molten sulphur instead of over its surface, while if the current is divided into a series of fine streams by being passed into the liquid through a perforated nozzle a still greater yield is produced. An advantage of the method is that the blast of charged air issuing from the generating apparatus can be discharged in any given direction and on to any definite object by an attached delivery tube. It can thus serve both for general fumigation and for direct spraying. There are considerable possibilities in connection with its application under open-air conditions, and it is hoped to test these during the coming season. At present forms of apparatus suitable only for laboratory

and small greenhouse work have been tested, but steps are being taken to devise and test modified types of apparatus to serve for large scale work.

A further method of fumigation has just come to notice through a short abstract published in the Review of Applied Mycology, Vol. I, 1922. This refers to a paper by Vogt in the Nachrichtenblatt für den deutschen Pflanzenschutzdienst, wherein is described by him a method of vaporising sulphur by passing through boiling sulphur a blast of steam under pressure. Apparently a cloud of particulate sulphur of substantially the same character as that described above is obtained and is capable of control in similar fashion. It appears, however, to be open to two objections: firstly, that the temperature of the sulphur is raised above ignition point, and secondly, that, in spite of the statement that no toxic gases are produced, it is likely that appreciable quantities of sulphuretted hydrogen are formed. In the course of our own work we have invariably found that, if sulphur containing any trace of water is boiled, material amounts of that compound are evolved.

CIDER-MAKING TRIALS—1920–21 SEASON.

By Otto Grove.

Variety Tests.

During the season 1920-21 the vintage apple crop was extremely poor and it was not possible to get more than a few tons of English cider apples of rather inferior quality. Consequently it was decided to get some apples from France, where the crop was a good one. These apples were all mixed varieties from the neighbourhood of Redon in the south of Brittany, and were mostly of the sharp kinds. It would have been desirable to get some single varieties and mixed fruit from other districts, but this was not done because of the high prices demanded for single varieties and the action of the French Government in stopping the export of cider apples before fruit from different districts could be secured. The apples were shipped directly from St. Malo to Bristol, where they arrived at the end of October. Unfortunately they had not stood the transport very well and were for the most part in bad condition, very bruised and to a certain extent decayed. Many had to be rejected. The charges for freight were rather heavy, making the cost of apples bought in France at about £5 per ton, amount to about £11 per ton delivered at the Institute.

As the apples arrived in over-ripe condition it was necessary to make them up as quickly as possible without attempting to sort them into different groups according to the types of apples. Consequently they were made up according to ripeness, taking the ripest lots first. In all 12 lots of cider were made. As the chemical analyses show, there was not a great difference in the composition of the juices. The ciders were all of the same class : quick fermenting, sharp, rather thin and without much body, but with a pleasant flavour. They kept well in bottle, but some which had been filtered at a comparatively high specific gravity (over 1020), produced too much deposit and gave too much effervescence when the bottles were opened.

These apples were too much of the sharp class to give a cider typical of that used in Brittany, where a lower degree of acidity is preferred. In another season of scarcity it is hoped that it will

Name of Variety.	District where Grown.	Date of Making.	Specific Gravity of Fresh Juice.	Malic Acid per cent.	Tannin per cent.	Rate of Fermentation at 25° C.	Date of Filtering.	Specific Gravity May, 1921.
SINGLE VARIETIES.								
SHARP VARIETIES.								
Crab Apple	Byford	Dec. 15th	1·048	1·09	·18	6·6	3/1/21	1·019
White Hereford	Breinton	Dec. 17th	1·044	·68	·17	5·2	10/1/21	1·017
BITTERSWEET VARIETIES.								
Dabinett	Long Ashton	Dec. 9th	1·056	·32	·24	6·4	13/1/21	1·012
Jersey	Breinton	Dec. 16th	1·046	·26	·18	5·2	17/1/21	1·023
Cummy Norman	Breinton	Dec. 17th	1·056	·26	·19	5·5	18/1/21	1·026
Royal Wilding	Ledbury	Dec. 7th	1·053	·24	·28	4·5	18/1/21	1·025
Royal Wilding	Breinton	Dec. 17th	1·052	·29	·18	3·7	17/1/21	1·030
MIXED APPLES FROM FRANCE.								
do. No. 1	Brittany	Nov. 1st	1·052	·68	·12	8·3	28/11/20	1·014
do. „ 2	„	Nov. 2nd	1·052	·81	·12	7·8	26/11/20	1·013
do. „ 3	„	Nov. 3rd	1·051	·78	·17	7·2	26/11/20	1·017
do. „ 4	„	Nov. 4th	1·051	·80	·13	7·2	28/11/20	1·018
do. „ 5	„	Nov. 8th	1·049	·80	·14	7·3	6/12/20	1·012
do. „ 6	„	Nov. 10th	1·048	·82	·11	8·2	6/12/20	1·007
do. „ 7	„	Nov. 12th	1·048	·78	·11	8·	7/12/20	1·007
do. „ 8	„	Nov. 12th	1·048	·81	·11	8·	8/12/20	1.011
do. „ 9	„	Nov. 16th	1·049	·84	·12	5·4	10/12/20	1·024
do. „ 10	„	Nov. 17th	1·050	·84	·13	4·2	13/12/20	1·024
do. „ 11	„	Nov. 18th	1·050	·83	·13	4·7	14/12/20	1·023
do. „ 12	„	Nov. 22nd	1·046	·92	·11	5·7	15/12/20	1·024

be possible to experiment with different types of French cider-apples under more favourable conditions.

As regards the few single variety ciders made up from English apples, the sample of crab apples gave a very sharp, light coloured cider, which was much too sharp and thin to be of any use by itself: but a cider of this type is sometimes useful to blend with some of the heavy bitter-sweet types, especially in the case of ciders liable to go black with exposure to the air, since the addition of malic acid prevents this disorder.

The White Hereford gave a thin, rather sharp cider. Of the bitter-sweet varieties, the two Royal Wildings were very good full-bodied ciders. The Cummy Norman was fairly good, but both the Dabinett and the Jersey were below the standard for the varieties.

In the preceding table a list of the apples tested is given with the chemical composition of the juices and other particulars.

Pure Yeast Fermentation Experiments.

An experiment was made with pure yeast fermentation. The juice used was made from a small lot of mixed apples, mostly Royal Wilding and Cummy Norman. The analysis of the juice was as follows:—specific gravity 1.050; malic acid ·31%; tannin ·20%; rate of fermentation at 25°C. 6·7.

One cask as a control was left to ferment naturally in the ordinary way. In the case of the other five casks, the juice was first pasteurised by heating to 70° C. (158° F.), and then placed in freshly steamed 50 gallon casks, where it was left to cool. Each was after cooling inoculated with two litres of a culture of a specially selected type of pure yeast, a different kind being used in each case. The casks were kept in a room where the temperature was maintained at 55°–58° F.

Although the casks were kept at the same temperature and were all of the same size, there were great variations in the rates of fermentation, as will be seen from the following table.

Specific Gravity.

	Dec. 20, 1920.	Jan. 3, 1921.	Jan. 6, 1921.	Jan. 10, 1921.	Jan. 17, 1921.	Jan. 24, 1921.	Jan. 28, 1921.
Control	1·050	1·026	1·018 (filt)	..	..	..	..
Yeast 27(Johannisberg)	1·050	1·042	1·033	1·025	1·022	1·018 (filt)	..
„ 37 (Riesling)	1·050	1·028	1·022	1·017 (filt)	..	..	..
„ 13 (Gatcombe Cider) ..	1·050	1·032	1·025	1·019 (filt)	..	..	..
„ 40 (Saké) ..	1·050	1·047	1·042	1·035	1·029	1·023	1·019 (filt)
„ 34 (Port wine)	1·050	1·041	1·036	1·032	1·028	1·024	1·020 (filt)

During the fermentations samples were taken for microscopical examinations and it was found that the yeasts added kept in a pure state without admixture of other yeasts. The samples were bottled directly after filtration and were compared for flavour and quality, after being kept in bottles for four months, the following being the observations made at the time :—

		Specific Gravity.		Order of Merit.
Control :	Cider clear with some deposit	1·016	A dry cider with moderate flavour	5
No. 27	„ „ „ „ „	1·014	Better than control Flavour cleaner	3
„ 37	„ „ „ „ „	1·013	Inferior to control. Coarse flavour	6
„ 13	„ „ rather less „	1·013	Decidedly superior to control. Best of all	1
„ 40	„ „ with some „	1·016	As control. A little cleaner in flavour	4
„ 34	„ „ rather more deposit	1·016	Better than control. Flavour cleaner	2

It will be seen that the pasteurisation of the juice and fermentation with a pure yeast in all cases had a marked retarding influence upon the rate of fermentation. After 17 days the specific gravity of the control had fallen from 1·050 to 1·018, but in the case of yeast, No. 40, it took 39 days to reach a specific gravity of 1·019. This is partly due to the character of the different yeasts and probably also to the fact that some of the nitrogen-containing substances in the juice are coagulated by the pasteurisation and made less readily available as food for the yeasts. In all our experiments with fermentations with pure yeasts in pasteurised juices this retarding influence has been more or less in evidence.

As regards the differences in flavour, it can be said that the samples fermented with pure yeast, with one exception, had a cleaner and more wine-like flavour than the control, and there does not seem to be any doubt that the pasteurisation of the juice and the fermentation with a carefully selected pure yeast would improve the flavour of the cider. No cooked taste could be observed.

The regular pasteurisation and application of a selected yeast would bring several advantages. Firstly, as mentioned above, the retarding of the rate of fermentation, which is very desirable, as it makes it easier to produce a sweet cider : and secondly, the elimination of disorders like sickness and ropiness and to a certain extent acetification. The micro-organisms causing these disorders are killed by the heat used for the pasteurisation, and consequently the maker has only to see to it that the fermentation-vats are sterilised, before the pasteurised juice is admitted, to prevent any infection with undesirable micro-organisms.

When fermenting cider in the ordinary way, a certain number of yeasts, torulae, *Sacch. apiculatus* types and other micro-organisms are more or less active during and after fermentation and make the control of the fermentation and the keeping quality of the cider rather uncertain, as they are influenced by many different factors. If the juice is pasteurised at the proper temperature it should be sterile, and consequently there would only be two principal factors to take into consideration in the making of the cider, namely, the quality of the juice and the character of the pure yeast used. Both these factors are largely under control, and it would be possible to produce any desired type of cider, with much greater security and facility than when working under ordinary conditions, with a juice containing a great number of more or less desirable organisms influencing the fermentation of the juice and the keeping quality of the cider.

The pasteurisation of the juice as it comes from the press is not difficult or costly to carry out. There are several forms of continuous pasteurisation apparatus on the market, and the use of one or other of these would make the method practicable on however large a scale it might be desired to conduct it.

THE BEHAVIOUR OF PECTIN TOWARDS ALKALIS AND PECTASE.*

By Frank Tutin.

Pectin is a plant product which plays a part of considerable importance in the jam and fruit-preserving industries, and problems connected with it also arise in the making of wine, cider, perry and other fermented beverages made from fruit juices. It is present in fruits and also in roots, such as carrot, turnip, etc., in which parenchymatous tissue is largely developed. A solution of pectin in presence of suitable quantities of sugar and an acid readily forms a gel, and it is to this property that the "setting" of jams and jellies is due. It may be prepared by the addition of alcohol to an aqueous extract of the respective fruit, when the pectin separates as a voluminous, gelatinous precipitate. Athough the product so obtained cannot be considered in the strict, chemical sense as a pure compound no doubt can be entertained that it is, essentially, an individual substance. It cannot be crystallised, and the only methods of purification which have, so far, been found practicable are treatment in aqueous solution with animal charcoal and reprecipitation with alcohol.

The literature on the subject of pectin is voluminous, but a perusal of it reveals a great deal of confusion, and contradictory statements are frequent.

The present communication embodies the results of some preliminary work on pectin, and deals with the action of alkalis and of the enzyme, pectase, on this substance. It has long been known that pectin, on treatment with an alkali, yielded pectic acid, a substance which is insoluble in water in presence of an appreciable amount of an electrolyte. More recently Th. von Fellenberg† has shown that the product obtained on distilling pectin with aqueous alkali contains methyl alcohol. Although he never made any thorough examination of the distillate he concluded, from indirect evidence obtained by several methods, that

* From the *Biochemical Journal*, Vol. XV, 4, 1921.

† Von Fellenberg. *Chem. Zent.* 1914. 11, 942.

methyl alcohol was the only volatile product formed. To the present author, however, this conclusion did not seem to be justified, and investigation has proved this to be the case. Lippmann* speaks of it as a well-known view that pectin it a methyl ester of "pectinic" acid, and attributes the presence of methyl alcohol in rum to the decomposition of pectin derived from thes ugar cane.

No definite information appears, so far, to have been obtained regarding the action of the enzyme, pectase, on pectin beyond the fact that it causes a solution of the latter to set to a stiff gel, and that this change occurs more readily in the presence of chalk. The production of the gel has been considered to be due to the formation of calcium pectate.

The present author finds that the actions of cold, dilute alkali and of pectase on pectin are essentially identical. In both cases a salt of pectic acid is formed and not only methyl alcohol, but also acetone, is eliminated. In this connection it is worthy of record that both methyl alcohol and acetone have now been found to be present in cider, being doubtless derived from the pectin, which becomes destroyed during the fermentation of the apple juice.

Both the acetone and the methyl alcohol are eliminated with great facility from pectin, a small quantity of $N/10$ alkali at ordinary temperatures being sufficient to set free both compounds. This would suggest that both of them were present as ester groupings, the acetone occurring as an ester of its enolic modification, *iso*propenyl alcohol, $CH_3.C(OH):CH_2$. It appears likely, therefore, that pectin is the dimethyl*iso*propenyl ester of pectic acid.

Experimental.

The pectin employed in this investigation, except where otherwise stated, was obtained from apples. Dried "pomace" (the "press cake" from the cider press) was heated to 100° with water and the liquid subsequently expressed. The pectin was then precipitated by the addition of alcohol to the dark-coloured solution, collected, pressed free from mother-liquor, and purified by solution in water and re-precipitation by alcohol. As thus obtained the pectin formed a brownish, voluminous, jelly-like precipitate, which could be deprived of a large volume of occluded mother liquor by careful pressing in a cloth. Further purification was effected by treatment with animal charcoal in dilute aqueous solution. The first treatment with animal charcoal caused an appreciable diminution of the amount of material in solution, but subsequent treatments resulted in the absorption of only small quantities of the pectin, thus indicating that the initial loss was due essentially to the

* Lippmann. *Biochem. Zeitsch.* 1920. 106, 236.

removal of impurities. On precipitating, the pectin after this purification separated as an almost colourless, jelly-like precipitate which, when dried, formed a greyish solid which could be reduced to a nearly white powder. The yield was nearly 5% of the weight of the dried pomace employed.

The action of alkali on pectin.—All samples of pectin were found to possess a slightly acid reaction and the purified material (dried in a vacuum) when titrated, neutralised immediately in the cold 1·05% of its weight of sodium hydroxide. On keeping, however, in aqueous solution at ordinary temperature in presence of an excess of the alkali a further amount of the latter equivalent to 12·35% of the weight of the pectin employed was taken up, the reaction being practically complete in half-an-hour, only a trace more akali being neutralised on keeping for a further 18 hours. On then adding an excess of acid to the solution pectic acid was precipitated. When pectin was heated to about 80° with excess of $N/10$ alkali, however, much more of the latter was neutralised, considerable darkening occurred, and no definite end-point to the reaction could be ascertained. Moreover, on acidifying the alkaline mixture after heating for two hours no pectic acid was precipitated.

It has been recorded by von Fellenberg [1914) that pectin yields methyl alcohol when distilled with an excess of aqueous alkali, and this reaction was therefore investigated. A considerable quantity of pectin, in aqueous solution, was treated with an excess of sodium hydroxide and the mixture distilled in a current of steam for some time. It was at once evident that the distillate contained something other than methyl alcohol since it readily yielded iodoform on treatment with iodine and an alkali. The entire distillate* was therefore submitted to a systematic process of fractional distillation, employing a Young's rod and disc column, when it was separated into water and a fraction boiling below 70°. The latter, after drying over quick lime, was re-fractionated several times, again employing an efficient column, when it passed over from 56–66° and was finally collected in eight fractions, all of which were analysed. The fraction boiling at 66° consisted of methyl alcohol (found : C = 37·5, H = 12·6%), whilst that boiling at 56–58° evidently consisted chiefly of acetone. It has a strong odour of the latter, gave C = 58·5, H = 10·8%, and readily yielded acetonesemicarbazone, melting at 186°. The regular change in the composition of the intermediate fractions, as shown by analysis, clearly indicated that no third substance was present. The proportion of acetone to methyl alcohol produced appeared to be about one part of the former to two of the latter.

* The original distillate was always alkaline owing to the presence of a trace of ammonia, doubtless derived from a small amount of protein material present as an impurity in the pectin. It was neutralised before fractionation.

Pectin was then treated in cold, aqueous solution with 13·4% of its weight of sodium hydroxide (the amount taken up by pectin in the cold), the mixture kept for 30 minutes, then made slightly acid, and distilled as before. It was then found that both acetone and methyl alcohol were formed, and to the same extent and in the same proportion as when the distillation had been conducted in the presence of a considerable excess of alkali. Moreover, when an amount of alkali sufficient to react with only half the pectin taken was employed both acetone and methyl alcohol were obtained, and apparently in the same relative proportions as when an excess of alkali had been used.

The action of pectase on pectin.—A quantity (13g.) of pectin was dissolved in 2 litres of water, a few grams of precipitated calcium carbonate added, and then 40 cc. of pectase solution introduced. This was prepared by pounding fresh clover in a motor with a little water and then expressing the liquid from the resulting mass. On keeping over night the whole mixture set to a jelly. The latter was broken by vigorous shaking and distilled in a current of steam. On fractionating the distillate it was found to contain acetone and methyl alcohol to the same extent as if the pectin had been distilled with alkali.

The contents of the distillation flask were then filtered, and the filtrate concentrated to a small bulk under diminished pressure and precipitated with alcohol. A small quantity of an amorphous solid was thus obtained, which was not unchanged pectin, but probably represented impurities in the original sample of pectin used, whilst the filtrate from this amorphous solid contained only a very small amount of material, largely dextrose, which was doubtless derived from the clover extract which had been added. Pectin, when treated with pectase in the presence of chalk*, therefore appears to yield only acetone, methyl alcohol and the gelatinous solid which consisted of calcium pectate, as shown below. The action of the enzyme, pectase, on pectin is therefore precisely analogous to that of sodium hydroxide, since the latter has been shown to convert pectin into acetone, methyl alcohol, and sodium pectate.

The solid particles of jelly which had been separated by filtration from the liquid in the distillation flash were macerated in the cold with dilute hydrochloric acid, the mixture filtered and the solid washed until free from calcium. After treatment in solution as sodium salt with animal charcoal the acid was reprecipitated washed, dried in a vacuum and analysed. Found: C = 39·2, H = 5·1, NaOH neutralised = 20·86%. Pectic acid prepared by

* Chalk was added since the presence of free acid retards the action of pectase.

the action of sodium hydroxide in the cold on pectin gave C = 39·4, H = 5·1, NaOH neutralised = 20·90%.

Pectin from other sources.—In order that the pectin from plants belonging to different Natural Orders might be compared with the product from apples, carrots, turnips and mangold wurzels were investigated. It was then found that the pectin from each of these sources behaved like that from apples when treated with pectase or with alkali, yielding in each case both acetone and methyl alcohol.

The product obtained from mangold wurzels, however, was obviously much less pure than apple pectin, and yielded quite an appreciable amount of ammonia when distilled with alkali.

THE CHEMISTRY OF THE APPLE.

By Frank Tutin.

In addition to the foregoing work on pectin an examination of the other constituents of the apple is in progress, and the results of a preliminary estimation of various products present in the seeds, peel and pulp respectively are given below. The variety of apple used was the cider apple, Royal Wilding. The products estimated were: (*a*), the fat (soluble in light petroleum); (*b*), the material soluble in either, but insoluble in petroleum and in water; (*c*), the material soluble only in alcohol; (*d*), substances soluble in both alcohol and water, and (*e*), the pectin. These various products are being separately investigated, and a number of crystalline substances not hitherto recorded as constituents of apples have already been isolated. The percentages of the various products, calculated both on the fresh and the dry material, are given in the following table:—

	FRESH MATERIAL.			DRY MATERIAL.		
	SEEDS.	PEEL.	PULP.	SEEDS.	PEEL.	PULP.
	%	%	%	%	%	%
Water	27·93	76·26	79·27	—	—	—
Fat	17·58	0·54	0·06	24·47	2·31	0·31
Ether soluble product	1·19	0·94	0·06	1·66	3·97	0·27
Material soluble only in Alcohol	Small amount.	0·31	Trace.	Small amount.	1·31	Trace.
Material soluble in Water and in Alcohol ..	3·51	14·55	17·26	4·96	61·27	83·18
Pectin	None.	2·61	1·39	None.	11·00	6·70

THE EFFECTS OF MURIATE OF POTASH AND SULPHATE ON THE COOKING AND KEEPING QUALITIES OF POTATOES.

By T. Wallace.

The experiment described below was carried out as the result of the large number of post-war enquiries received regarding the probable bad effects produced on the quality of potatoes by growing them with muriate of potash. This question has assumed great importance since the war, owing to the fact that whereas we in this country are dependent on Germany for the large proportion of our supplies of sulphate of potash, we can obtain supplies of muriate of potash from the mines of Alsace-Lorraine, and from the flue-dust of the blast furnaces of this country.

The opinion that muriate of potash does affect the quality of potatoes adversely is very widely held by farmers, but this opinion does not appear to have the support of any recorded experiments.

Plan of Experiment.

The experiment was carried out on one early variety—Sharpe's Express—and on one maincrop variety—Scottish Farmer.

In the case of each variety there were three plots under differential manurial treatments, viz :

Sharpe's Express Plots.

Plot A.—Control Plot.—Dressed with town stable manure and nitrogenous and phosphatic manures.

Plot B.—Muriate of Potash Plot.—Dressed with manures as in Plot A, and muriate of potash.

Plot C.—Sulphate of Potash Plot.—Dressed with manures as in Plot A, and sulphate of potash.

Scottish Farmer Plots.

Plot A.—Control Plot. Dressed with nitrogenous and phosphatic manures only.

Plot B.—Muriate of Potash Plot.—Dressed with manures as in Plot A, and muriate of potash.

Plot C.—Sulphate of Potash Plot.—Dressed with manures as in Plot A, and sulphate of potash.

The details of the manuring of the plots are given in the detailed accounts of the plots of the two varieties.

The crops obtained from the plots were treated for experimental purposes as follows :—

(*a*) The yields from each plot of ware potatoes, seed potatoes and " chats " were determined.

(*b*) Even samples of medium sized potatoes—each sample weighing 1 cwt.—were selected from the crop of each plot to carry out the following tests and laboratory determinations.

(1) Determination of percentage of dry matter in the tubers.

(2) Determination of percentage of total nitrogen in the tubers.

(3) Determination of loss in weight of tubers on keeping for a considerable period.

(4) Determination of keeping qualities of the tubers.

(5) Cooking tests at various intervals after date of lifting.

Methods adopted in carrying out Tests.

(1) Determinations of percentages of dry matter and of total nitrogen were carried out in the usual manner immediately after the crops were lifted.

(2) To determine the loss of weight on keeping, one hundred potatoes from each plot were placed side by side on a perforated zinc tray. The trays containing the samples from the various plots were kept on shelves in a cool dry room lighted by a window facing due north, the potatoes being exposed to this light. The samples of potatoes were weighed in bulk at intervals and the loss in weight determined.

(3) In order to test the keeping qualities, the potatoes left over from each of the 1 cwt. samples, after samples had been drawn for the various tests described above, were kept in sacks in a cool dry room and observations made at intervals on their keeping qualities.

(4) In the cooking tests some samples of the potatoes were boiled without removing the skins and some baked without removing the skins. The freshly cooked potatoes were tasted by numerous observers, who attempted to place the samples in order of "mealiness," and observations were made on the relative tendencies of the cooked samples to blacken.

Weather.

The weather during the growing season was abnormally dry and hot during the spring and summer, and abnormally mild and with the rainfall below the average during the autumn. During the period over which the early variety occupied the ground scarcely any rain fell and the soil of the plots was generally very dry.

The soil of the Scottish Farmer plots remained very dry until the middle of August, when there were some heavy showers of rain, after which the plants began to make vigorous growth. From this time it was observed that many of the tubers began to make secondary growths, and on examining the tubers after lifting it was noted that the tubers from all the plots varied greatly among themselves. Some of them—presumably of primary origin—had thick tough skins, whilst the later formed ones had thin skins, which could be easily broken by rubbing with the fingers.

In carrying out the tests on this variety, potatoes were used which were judged to be of the same degree of maturity and samples of the mature and immature potatoes from the various plots were put aside as separate samples for tests on keeping quality.

Soils of the Experimental Plots.

Samples of the surface soil were taken for analyses from the areas used in the two experiments, prior to the application of the manures. The results of the analyses are appended in Table III.

EXPERIMENT WITH SHARPE'S EXPRESS.

Plots.—The area of each plot was approximately 1/20th of an acre.

Planting.—The potatoes on all the plots were planted during the period April 8th-April 11th.

Manurial Treatment.—The following manurial dressings were applied to all the plots.

5 tons of Town Stable manure per acre, applied winter 1920-21.

2 tons of Shoddy (6-7% Nitrogen) per acre, applied winter 1920-21.

1 cwt. Sulphate of Ammonia per acre, applied April 7th, 1921.

4 cwt. Superphosphate, per acre, applied April 7th, 1921.

In addition, the potash plots received dressings of muriate and sulphate of potash respectively to supply 58 lbs. of potash (K_2O) per acre on April 7th, 1921.

Lifting.—The crops were lifted on August 24th and 25th, by which time the haulms had completely died down.

Disease.—Almost the whole of the tubers lifted from the plots were affected to some extent with common scab, and appeared to be free from other diseases.

Plot Yields and Results of Laboratory Tests.

The results of plot yields, dry matter and nitrogen determinations are appended in Table 1.

Cooking Tests.

Cooking tests were carried out on September 20th and December 15th. On both occasions ten observers took part in the tests and the results obtained showed no agreement as to any one sample of potatoes, differing greatly from the others. Indeed, many of the observers were of opinion that the differences among the potatoes of any sample were as marked as any difference between the samples from the three plots.

As regards the blackening observed among the potatoes on standing, on both occasions there was very little blackening observed in any of the samples used in these tests, even after the samples had stood at room temperature overnight, and there were no differences to be observed between the samples themselves.

Keeping Qualities.

Periodical examinations were made up to January 21st, 1922, up to which date no essential differences were observed between the different samples. By the end of November, 1921, the potatoes in the sacks had sprouted considerably and felt soft, and by January 21st, 1922, they were obviously unfit for ware purposes.

Loss in Weight of Tubers on Keeping.

The results obtained during the period August 26th to October 29th, on the rates of loss in weight of the tubers selected for this purpose are tabulated in Table II. After this latter date, the potatoes began to sprout considerably and as this would necessarily complicate the rate of loss in weight of the tubers the results obtained to this date only are given.

Examination of the results shows that the tubers from the two plots receiving potash salts lost in weight at approximately the same rates throughout the period, whilst the rate of loss in weight of the tubers from the control plot was considerably faster than the rates of loss in weight of those from the potash plots.

Experiment with Scottish Farmer.

Plots.—The area of each plot was approximately 1/18th acre.

Planting.—Planting was carried out during April 18th and 19th.

Manurial Treatments.—All plots were given the following dressings of manures.

2 tons of Lump Lime per acre, applied winter 1920-21.
2 tons of Shoddy (6—7% Nitrogen) per acre, applied winter 1920-21.
1 cwt. Sulphate of Ammonia per acre, applied April 17th, 1921.
4 cwts. Superphosphate per acre, applied April 17th, 1921.

The potash plots were dressed with the respective potash salts to supply 58 lbs. of potash (K_2O), per acre.

Lifting.—The crops were lifted on October 14th and 15th.

Disease.—The tubers appeared to be entirely free from disease at the time of lifting.

Plot Yields and Results of Laboratory Tests.

These are appended in Table I.

Cooking Tests.

Cooking tests were carried out on November 16th, 1921, and January 18th, 1922. As in the tests with Sharpe's Express, the results obtained failed to show any distinct differences between the quality of the different samples as regards palatability.

As regards the tendencies of the potatoes of the different samples to blacken, it was observed on both occasions that the potatoes from the control plot showed considerable blackening both in the boiling and baking tests after standing for about 10-15 minutes, whilst those from the potash plots showed scarcely any blackening even after standing over-night at room temperatures.

Keeping Qualities.

Up to January 21st, 1922, the mature potatoes from all three plots had remained very firm and had sprouted only very slightly. Some of the immature potatoes were quite soft and were probably unfit for ware purposes.

Loss in Weight of Tubers on Keeping.

Observations were carried out over the period October 20th, 1921—January 20th, 1921. Only tubers which appeared to be ripe were used, as it was thought that consistent results would not be obtained if unripe tubers were used.

The results obtained in this experiment are similar in character to those obtained in the experiment with Sharpe's Express, *i.e.*, the tubers from the two potash plots lost in weight at practically equal rates, whilst those from the control plot lost in weight at a considerably greater rate than those from these two plots. This was especially the case up to November 11th, 1921.

Discussion of Results.

In considering the results obtained in these experiments, it is well to bear in mind the facts that the weather conditions during the season of 1921 were very abnormal, and that the season was unsuitable for the carrying out of an experiment on potatoes. Some of the results obtained may, therefore, be peculiar to the conditions which existed during the season and it is desirable that the experiment should be repeated in a more normal season.

Yields.

In the experiment with Sharpe's Express no increase in the yield of tubers was obtained by the use of either muriate or sulphate of potash. In this connection it should be noted that all three experimental plots received light dressings of town stable manure. In the Scottish Farmer plots, where no dung was applied, an increase in yield of 26% over that of the control plot was obtained by the use of the muriate of potash. The increase obtained on the sulphate of potash plot, viz., 8·4%, is probably well within the limits of experimental error.

Laboratory Tests.

In both experiments it was found that the tubers from the plot giving the lowest yields contained the highest percentages of dry matter, whilst those from the plots giving the highest yields contained the lowest percentages of dry matter.

This relation also held between the yields of tubers and the percentages of total nitrogen contained in the tubers in the experiment with Sharpe's Express. In the experiment with Scottish Farmer, the percentages of total nitrogen found in duplicate determinations showed considerable differences.

Cooking Tests.

In view of the great diversity of opinion shown in these tests, it may be safely said that muriate of potash does not appear to have adversely affected the quality of the potatoes grown in these experiments.

Further, in the experiment with Scottish Farmer, both the muriate and sulphate appeared to have affected the composition of the potatoes in some way, as was shown by the fact that potatoes from these plots after boiling or baking did not blacken so readily on standing as those from the plot receiving no potash salts.

This difference was not observed with the Sharpe's Express potatoes, in which experiment town stable manure had been applied to all three plots.

Keeping Qualities.

In neither experiment did either of the potash salts appear to have affected the keeping qualities of the tubers in any way.

Loss in Weight of Tubers on Keeping.

In both of the experiments the tubers from the muriate and sulphate plots lost in weight at approximately equal rates, which rates were slower than those at which the tubers from the respective control plots lost in weight. It would appear from these results that potash plays some part in regulating the rate at which moisture is given up from the cells of potato tubers.

TABLE I.

VARIETY—SHARPE'S EXPRESS.

Plot.	Details of crops.	Nos. of tubers per plot.	Yields of tubers per plot. (lbs.)	Yields of tubers per acre. (tons.)	Dry matter in tubers. %	Yields of dry matter per acre (tons.)	Total Nitrogen in tubers. %
Control	Ware	4085	690·5				
	Seed	1802	143·5				
	Chats	2516	78				0·382 / 0·380 } 381
	Totals	8403	910	8·12	25·11	2·04	
Muriate of Potash.	Ware	3803	630				
	Seed	1645	127				
	Chats	2798	78·5				0·403 / 0·415 } 0·409
	Totals	8246	835·5	7·45	25·73	1·91	
Sulphate of Potash.	Ware	3937	603				
	Seed	2044	158·5				
	Chats	3825	110·5				0·382 / 0·384 } 0·383
	Totals	9806	872	7·78	25·21	1·96	

VARIETY—SCOTTISH FARMER.

Control	Ware	2966	594					
	Seed	2193	178					
	Chats	4896	163				0·354	0·378
	Totals	10055	935	7·50	21·39	1·60	0·410	
Muriate of Potash.	Ware	4227	784					
	Seed	2486	209					
	Chats	5331	180				0·359	0·353
	Totals	12044	1173	9·41	19·59	1·84	0·347	
Sulphate of Potash.	Ware	2818	657					
	Seed	2044	193					
	Chats	4829	183				0·358	0·385
	Totals	9687	1013	8·13	20·04	1·63	0·411	

TABLE II.

SHOWING RATES OF LOSS IN WEIGHT OF 100 TUBERS.

VARIETY—SHARPE'S EXPRESS.

Dates of Weighings.	Potatoes from Control Plot.		Muriate of Potash Plot.		Sulphate of Potash Plot.	
	Total Weight of Tubers. Kilo-grammes	Total loss in Weight of Tubers. Kilo-grammes	Total Weight of Tubers. Kilo-grammes	Total loss in weight of Tubers. Kilo-grammes	Total Weight of Tubers. Kilo-grammes	Total loss in weight of Tubers. Kilo-grammes
1921						
Aug. 26th.	7·995	—	7·995	—	8·003	—
,, 27th.	7·970	0·025	7·979	0·016	7·994	0·009
,, 29th.	7·928	0·067	7·950	0·045	7·956	0·047
,, 30th.	7·910	0·085	7·934	0·061	7·932	0·071
,, 31st.	7·900	0·095	7·928	0·067	7·920	0·083
Sept. 1st.	7·881	0·114	7·915	0·080	7·918	0·085
,, 3rd.	7·876	0·119	7·900	0·095	7·913	0·090
,, 5th.	7·852	0·143	7·885	0·110	7·891	0·112
,, 7th.	7·815	0·180	7·854	0·141	7·858	0·145
,, 9th.	7·801	0·194	7·837	0·158	7·840	0·163
,, 12th.	7·791	0·204	7·830	0·165	7·826	0·177
,, 16th.	7·779	0·216	7·818	0·177	7·820	0·183
,, 23rd.	7·763	0·232	7·803	0·192	7·805	0·198
Oct. 6th.	7·708	0·287	7·757	0·237	7·755	0·248
,, 29th.	7·611	0·384	7·698	0·297	7·693	0·310

VARIETY—SCOTTISH FARMER.

1921.						
Oct. 10th.	16·180	—	15·67	—	14·80	—
,, 22nd.	15·800	0·170	15·59	0·08	14·71	0·09
,, 24th.	15·520	0·310	15·44	0·15	14·56	0·15
,, 26th.	15·370	0·390	15·24	0·20	14·37	0·19
,, 29th.	15·280	0·420	15·03	0·21	14·17	0·20
Nov. 1st.	15·200	0·510	14·81	0·22	13·89	0·28
,, 11th.	15·060	0·610	14·45	0·36	13·47	0·42
,, 20th.	15·050	1·070	13·59	0·86	12·55	0·92

TABLE III.

SOILS OF THE EXPERIMENTAL PLOTS.

Formation: New Red Sandstone—Keuper Marl.

	Research Station, Long Ashton. Plot 8. Sharpe's Express Plot. (Surface Soil)	Research Station, Long Ashton. Plot 24. Scottish Farmer Plot. (Surface Soil)
Mechanical Analysis—	%	%
Stones in Sample	Nil	Nil
Fine Gravel	0·75	0·34
Coarse Sand	7·93	10·42
Fine Sand	52·40	36·26
Silt	10·61	10·87
Fine Silt	14·88	19·16
Clay	7·09	11·14
Chemical Analysis—		
Moisture	1·18	3·61
Loss on Ignition	5·13	7·44
Total Potash (K_2O)	0·710	0·839
Available Potash (K_2O) ..	0·0143	0·0092
Total Phosphoric Acid (P_2O_5)	0·131	0·112
Available Phosphoric Acid (P_2O_5)	0·038	0·0127
Calcium Carbonate	0·225	Contained some lime
Lime Requirement	Nil	Nil

POT EXPERIMENT ON THE MANURIAL VALUE OF CERTAIN RADIO-ACTIVE RESIDUES IN WHICH THE RADIO-ACTIVITY IS DUE TO THE PRESENCE OF RADIO-THORIUM.

By T. Wallace.

Several experiments have been carried out during recent years with radio-active materials with a view to ascertaining whether such materials containing relatively small amounts of active matter possess any manurial value.*

The view has been advanced that such substances in virtue of their radio-active properties might act as stimulants to plant growth, i.e., they would serve to speed up the physiological processes taking place within the plant.

The results of previous experiments have shown on the whole that in the present state of our knowledge of the use of these substances as fertilisers we cannot hope to gain any certain increases in yields of crops by their use and indeed the use of such materials may lead to the obtaining of decreases in the yields.

A novel suggestion as to the part played by radio-active material in plant physiology has been advanced by H. Zwaardemaker,† and in discussing this suggestion H. V. Blackman‡ has put forward the view that the conflicting results obtained in the various experiments carried out with radio-active substances may be due to the ease with which toxic concentrations are reached.

In view of the fact that manures appear on the market from time to time as being of special value in virtue of their containing radio-active substances, it appears desirable that further experiments and trials should be carried out to determine whether radio-active substances are capable of producing increased crop yields and to test any such materials which are put on the market or are available for fertilising purposes.

* *Journal of the Board of Agriculture*, Vols. XXII, XXIII.

† *Journal of Physiology*, 1920, 53.

‡ *Ann. Bot*, 34, 1920, No. 135.

The material used in the experiment described below is the residue left over from some ores containing meso-thorium from which the latter substance had been removed as completely as it was profitable to do so commercially.

A sample of the residues was forwarded to this station in June, 1920, as the owner of them was desirous of obtaining information as to their manurial value.

Experimental.

A preliminary pot experiment was carried out with lettuce and mustard plants in 1920 to ascertain whether the residues were likely to contain toxic substances in any quantity and as the plants in the treated pots did not show any signs of the residues being toxic at the rates of the dressings applied, a quantitative experiment was carried out during 1921.

The crops chosen for the experiment were peas and mustard. They were grown in 10in. pots, which had been waxed previously to render them more impervious to water. Each pot contained 7 kilograms of ordinary potting soil.

Forty-two pots were used in the experiment and were utilised as follows :—

Twenty-one pots were used for the experiment with peas and twenty-one for the experiment with mustard.

For the purpose of carrying out differential treatments, each group of twenty-one pots was divided into four main series—A, B, C, D,—each series consisting of five pots, and a series E, consisting of one pot only. The pots of the series were treated as follows :—

Series A.—Control Series. No residues added.

Series B.—1 grm. per pot of residues added — containing material with α activity equiv. to 0.00013—0·00014mgms. Ra Br_2 .2 H_2O
and γ activity equiv.to 0.00015 mgms.Ra Br_2.2 H_2O

Series C.— 2 gms. per pot of residues added.

Series D.— 6 gms. ,, ,, ,,

Series E.—20 gms. of residues added to the pot.

In Series B, C, D, of each experiment, the residues were added directly to the soil of three pots per series—numbered 3, 4, 5, in each series in the pea experiment, and 8, 9, 10, in each series in the mustard experiment—and were contained in test tubes, fitted with corks, sunk in the soil of the pots to a depth of 2ins. in two pots per series—numbered 1, 2, in each series in the pea experiment, 6, 7, in each series in the mustard experiment. In Series E. in both experiments the residues were added direct to the soil.

The object of adding the residues in these ways was to ascertain whether any of the effects produced—either positive or negative—

were due to radio-activity or to the presence of substances in the residues acting directly as foods or as toxins. The containing of the residues in the test tubes would cut off all radio-activity due to α rays and a considerable proportion of that due to β rays. Activity due to γ rays would not be affected.

The strengths of the residues were determined on two occasions —June, 1920, and January, 1922. The activities on these dates were as under:—

Date.	Activities expressed as equivalent to milligrammes of radium bromide ($Ra\ Br_2 .2\ H_2O$) per kilogramme.		
	α	β	γ
June, 1920 ..	0·1	Not determined	0·05
Jan., 1922 ..	0·15	do.	0·20

As the activity curves are nearly straight lines the approximate activities during the period of the experiments can be deduced. Thus the value of the α activity would average about 0.13—0.14 over the period in 1921 and that of the γ activity about 0.15.

The experiment was carried out in a glass-roofed shed with open sides, the pots of the different series being placed about 4ft. apart.

Experiment with Pea Plants.

The seeds were sown in sand contained in boxes on April 20th, and two plants per pot were transferred to the pots on April 28th.

The plants were harvested on August 16th on which date all the plants were ripe with the exception of those in pots C4, 5, where the plants were still rather green.

Throughout the growing period all the plants looked quite healthy and normal with the exception of those in Series E. These latter plants always looked poor and were of an unhealthy yellow colour.

The details of the crop yields are given in Table I.

Experiment with Mustard Plants.

Six mustard seeds per pot were sown in the pots on April 20th. The seeds in all the pots germinated well and no effect—either in favour of or against—appeared to be produced by the residues. The plants were singled out to two per pot on April 29th. During the course of the experiment one of the plants in pot D 10 was damaged by slugs and the result obtained for this pot is not included in the results of the experiment given in Table II.

Throughout the growing period all the plants made good growth and appeared to be healthy and vigorous, those in pot E 6 appearing to be the best of all. The crops were harvested in a ripe condition on August 16th.

TABLE I.—SHOWING YIELDS OBTAINED IN EXPERIMENT WITH PEA PLANTS.

Pot Number.	Yields—Dry Weights of Plants and Peas (Grammes).									
	Series A.		Series B.		Series C.		Series D.		Series E.	
	Plants.	Peas.	Plants.	Peas.	Plants.	Peas.	Plants.	Peas.	Plants.	Peas.
1 ..	20·70	9·81	21·69	9·74	13·90	5·19	14·90	6·99	8·22	3·59
2 ..	17·52	8·84	18·46	8·75	17·01	8·56	18·13	9·09		
3 ..	15·45	6·99	14·55	5·45	15·57	6·95	10·85	4·86		
4 ..	16·42	8·41	16·26	7·21	14·72	5·90	7·26	3·29		
5 ..	11·49	5·71	13·99	6·85	15·75	6·87	10·94	5·33		
Totals.	81·58	39·76	84·95	38·00	76·98	33·47	62·08	29·56	—	—
Averages per pot ..	16·32	7·95	16·99	7·60	15·39	6·69	12·42	5·91	8·22	3·59

TABLE II.—SHOWING YIELDS OBTAINED IN EXPERIMENT WITH MUSTARD PLANTS.

Pot Number.	Yields—Dry Weights of Plants (Grammes).				
	Series A.	Series B.	Series C.	Series D.	Series E.
6 ..	24·00	18·17	19·80	23·48	24·77
7 ..	27·48	18·22	24·44	34·49	
8 ..	24·75	18·73	23·35	22·47	
9 ..	22·37	23·61	17·21	21·44	
10 ..	23·47	24·12	22·65	—	—
Totals	122·07	102·85	107·45	101·88*	—
Averages per pot ..	24·41	20·57	21·49	25·47*	24·77

*4 pots only.

Discussion of Results.

Pea Experiment.—Series B. showed a slight increase in the weight of plants produced over Series A, but the amount was too small to be of significance. In Series C, D, E, the average weights of the plants per pot produced were less than in Series A, the decreases being considerable in Series D. and E. The plants in Series E. appeared to be unhealthy and the dose given was probably toxic. The weights of plants produced in pots D, 3, 4, 5, were considerably smaller than those in pots D. 1, 2, which appeared to indicate that the residues when added direct to the soil in this amount were toxic.

The highest total yield of peas was obtained in Series A, the total yields obtained in Series C, D being considerably below this, whilst the weight of peas obtained in Series E. was only about half of the average weight of peas per pot obtained in Series A.

In this experiment there was no evidence obtained of any beneficial effects on the plants resulting from the application of the radioactive material. There was some evidence that the material when applied at the higher rates was toxic to the plants.

Mustard Experiment.—The results obtained in this experiment were inconclusive. In two Series B. and C, in which the residues were added, decreases in the weights of the plants produced were obtained, whilst in Series D, E slight increases in crop weights were obtained.

There was no evidence in this experiment of the residues producing toxic effects.

Conclusion.

In conclusion the author wishes to express his thanks to Doctor L. A. Levy, M.A., F.I.C., 31, Shoot-up Hill, Cricklewood, London, N.W., for his kindness in determining the activities of the residues on the two occasions mentioned in this paper.

ADVISORY WORK.

The number of enquiries received during the year ending September, 30th, 1921, was 371, thus showing an increase of 80 over last year. The figures for the counties as well as totals and the corresponding figures for previous years are set out as below:—

	Year ending September 30th.				
	1917.	1918.	1919.	1920.	1921.
Gloucester (including Bristol) ..	24	21	29	53	73
Hereford	6	2	6	10	22
Somerset	52	46	75	79	96
Wiltshire	4	0	6	3	10
Worcester	16	11	11	29	45
Other areas	31	93	75	117	125
	133	173	202	291	371

The figures for "other areas" include Devon and Monmouth, which counties contribute an annual grant to the Institute. Last year the enquiries received from the Ministry of Agriculture's Experimental Station on Fruit and Vegetable Preservation at Campden were included in the totals for "other areas," but this year they have been omitted.

Nature of Enquiries.

Fruit Products.—Under this head 80 replies were given. The geographical field from which the enquiries came was wide, only 25 coming from the Advisory area. Most of the subjects could be grouped under such general headings as Conposition of Fruits; Fermentation of Fruits; Cider Making in general; Cider Making Machinery; Yeasts; Vinegars. Enquiries outside this country were received from Isle of Jersey, Ireland, France, Belgium, Australia and India. Two special visits were made to orchards in conjunction with the county horticultural instructor, in connection with suitable cider varieties.

Enquiries relating to methods of fruit and vegetable preservation were also received, but are not included in the above statistics, having been dealt with as a separate part of the work of the Station in conjunction with the Experimental Factory in Fruit and Vegetable Preservation at Chipping Campden.

Mycological.—The number of enquiries received during the past twelve months are as follows :—

Somerset	27
Gloucester	25
Worcester	14
Hereford	5
Wilts	4
Outside areas	12
	87

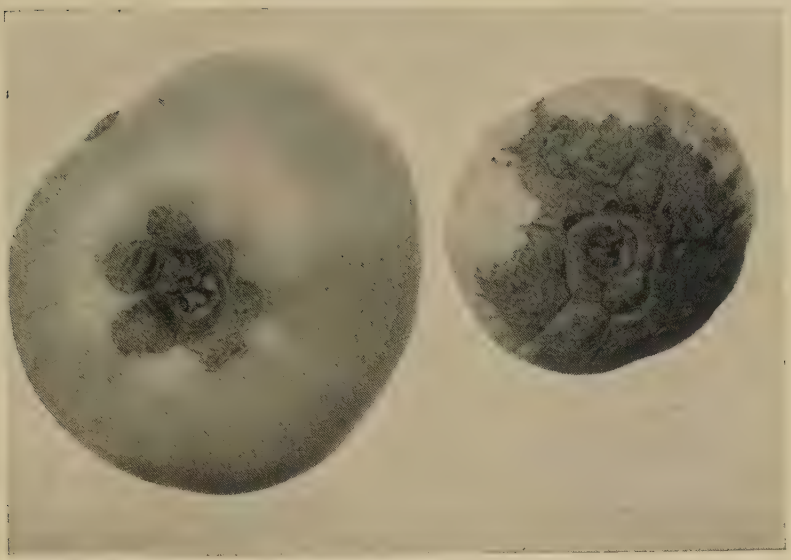
The enquiries received dealt with a large variety of plant diseases, some of them very obscure, whilst others were well known. Silver Leaf formed the subject of seven enquiries, dealing usually with particular points of this disease. Many enquiries were received on other diseases showing that these were fairly well distributed.

A feature of the year was the occurrence of a disease on raspberries, which was reported from Somerset and from Worcestershire. The symptoms of the disease were chiefly evident in the Spring season and consisted in the failure of the buds to open out, especially those towards the top of the canes, and the dying back of the canes. New shoots grew up from the ground during the summer and produced canes which, although somewhat shorter than usual on account of the dry weather, were quite healthy. The trouble was sometimes associated with an attack of the raspberry moth, but the latter insect was insufficient to account for the whole of the damage. No fungus has been found in the dead buds or in the stem, the tissues of which appeared to be quite healthy. So far as the present evidence goes, therefore, one is inclined to suspect climatic factors. But it is not possible on the data at present available to assign any definite reason for the trouble, and this subject requires fuller and more detailed research.

Another interesting disease encountered was a Fusarium parasite of carnations. This disease is apparently not uncommon in carnation beds, the symptoms being a wilt and subsequent death of a branch, or even of the whole plant. It has been reported from from South Africa and British East Africa, but appears to be known also in England.

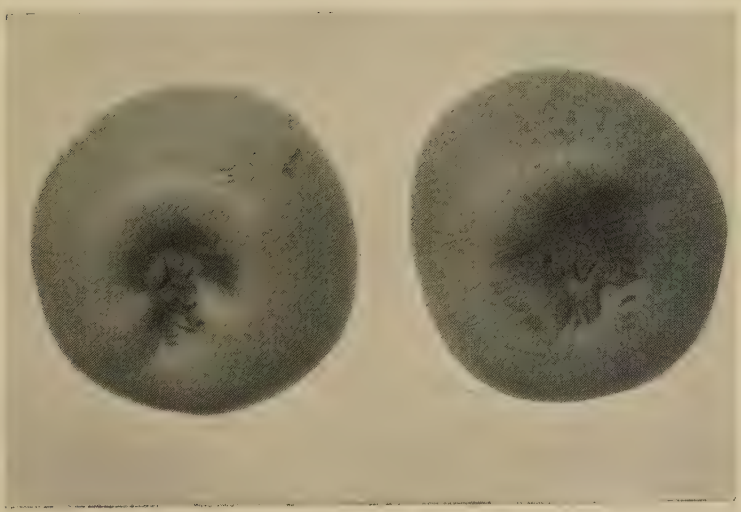
One case occurred of Crown Gall on loganberries, a rather uncommon occurrence. Brown Rot (*Sclerotinia fructigena*) was found on peaches growing out-doors. One instance of cherry disease, where the leaves showed sudden browning, followed by death, was encountered. The browning was frequently seen to start near the mid-rib. No fungus or bacterial organism could be found in the affected material, and whilst bacterial activity could not be ruled out altogether, the available evidence pointed to the disease not being due to any parasitic organism.

Fig. 2.



Apical Browning.

Fig. 3.



Late Apical Browning.

A non-parasitic disease of apple fruits, recently labelled "apical browning" was very abundant during this season. Stirling Castle was the most susceptible of all varieties, Bramley coming next, whilst other varieties only occasionally showed the disease. The first damage occurred very early in the season and early symptoms frequently showed when the fruits were about half an inch in diameter. The first signs of the disease appeared to be a splitting of the epidermal tissue close to the calyx. This splitting continued throughout the season, probably on account of the continuous swelling of the fruit, so that finally large scars were formed round the apical end of the fruit, which disfigured it very much. The scars, however, were always confined to the outer layers of the fruit, and, therefore, the chief damage consisted in the unsightly appearance it produced. On the Continent the opinion is held that the damage is due to frost-action, but in England the regularity of its appearance on Stirling Castle rather detracts from this view. It is noticeable that the scars only form in fruits with short cores, and it would appear possible that this characteristic construction sets up strains in the swelling fruits which give way at the weakest point, viz., just outside the calyx.

Another type of "apical browning," which may, perhaps, be dintinguished by the term "late apical browning," occurred on Bramleys at the Research Station, and was also found in a number of cases of Bramleys exhibited at the Imperial Fruit Show. This affection only made its appearance in August and September, and consisted of a browning of the tissue from the disc of the fruit for some little distance into the flesh of the apple just beneath the surface. Plate cultures were made, using as inoculant material from the browned portion of the fruit. No organism could be distinguished in such browned portions, and it is probable, therefore, that the browning is non-parasitic. It is noteworthy that the Bramley is the variety affected, and it may be that the growth strains caused by the swelling of the fruit, result in this case in the splitting of the tissues at the disc. A great lengthening of the tissue between the stamens and calyx during the growth of the fruit is evident from cutting fruits vertically through the core. The core of Bramleys, as mentioned above, remains very short, and hence any sudden increase in the rate of growth occasioned, perhaps, by heavy rainfall after drought, might well cause ruptures such as described.

Pomological.—Under this head 41 replies were given by letter. In addition, at least another 20 were furnished verbally. Owing to the good apple year and the large number of trees which bore a crop this year, many owners were anxious to obtain identification of trees which in other years probably failed to set crops. Such trees generally belong to private persons, and are thus frequently

out of the way kinds or even seedlings. The identification of such varieties is often very laborious and occupies much time. One consignment occupied two days before every apple could be identified.

Shows.—An exhibit from the Station was sent to the following Shows :—

(1) The West Midland Show, at Worcester.

(2) The Bath and West, at Bristol.

(3) The Pershore Fruit Growers' Association, at Pershore.

The following sections dealing with the Advisory Work in Agricultural Chemistry and Economic Entomology have been contributed respectively by Mr. T. Wallace and Mr. A. H. Lees, the advisers in those subjects.

Agricultural Chemistry.

During the year 56 requests for advice have been dealt with. The sources and nature of these enquiries, together with any special points of interest with reference to them, are given below.

SOURCES OF ENQUIRIES :—

Gloucester (including Bristol)	14
Hereford	3
Somerset	23
Wiltshire	3
Worcester	11
Counties outside the Bristol Province	6
Total	60

NATURE OF ENQUIRIES :—

1.—Soil Problems.

(*a*) *Soil Manurial Enquiries.*

Pastures and Meadows	5
Arable Soils	15
Fruit Soils	14
Garden Soils	5
Total	39

(*b*) *Miscellaneous Soil Problems.*

Soil conditions in cases of "Leaf Scorch"	4
„ „ „ disease of Michaelmas Daisies	1
„ „ „ cases of Finger and Toe disease	2
„ „ „ „ „ total failure of crops	10
„ „ „ case of "Stripe" in Sweet Peas	1
Suitability of soils for apple growing	6
„ „ „ strawberry growing	2
„ „ „ wheat growing	1
Use of phenol and cresylic acid for soil sterilisation	1
Total ..	28

2.—Miscellaneous Enquiries.

Manurial value of sample of chrome leather clippings	1
„ „ „ „ „ scutch	1
„ „ „ „ „ waste hair	1
„ „ „ „ „ lime material containing sodium sulphide	1
„ „ „ „ „ mineral deposit from Carboniferous Limestone Formation	1
„ „ „ basic superphosphate	1
„ „ „ waste "blood and bone" material ..	1
„ „ „ lime and limestone	9
„ „ „ shoddy	2
Potash content of sample of burnt paper ash	1
Total	19

OBSERVATIONS ON ENQUIRIES.

1.—*Soil Enquiries.*—In dealing with these enquiries, 15 farms —other than those visited on the Pershore tour—have been visited, and 72 samples of soil have been examined. In most cases where enquiries have been sent in relating to poor crops or total failures of crops, the soils in question have been found to be acid in reaction. Thus of the 10 cases of total failures of crops investigated, eight of the soils contained no lime and had considerable "lime requirements." Thus the necessity of farmers having their soils tested for lime is again demonstrated.

Other points worthy of note are the increasing number of enquiries *re* the manuring of fruit soils, the number of enquiries *re* the suitability of land for apple-growing, and the number of enquiries *re* "Leaf Scorch."

Investigations are now in progress on these three subjects of enquiry, and are furnishing much useful information.

2.—*Miscellaneous Enquiries.*—The whole of these enquiries have related to materials of probable manurial value, and it is interesting to see that farmers are beginning to recognise that many forms of waste material may have some manurial value.

Most of the samples of lime and limestone submitted for examination were articles which farmers had been offered at compara-

tively low prices, and while some of the samples were well worth purchasing, others were poor and the prices asked for them too high.

From the nature of the enquiries about lime it is evident that the price of high grade lime is higher than most farmers are able to pay.

As so much land at the present time is in need of lime and as liming is so costly, there is no doubt that it would be well worth while advisers giving a considerable amount of time to the problems of " liming of soils," and to exploring cheap sources of lime.

Special Investigations and Work Undertaken in an Advisory Capacity.

(1) Field Experiments on " The Eradication of Bracken from poor Moorland Pastures."

These experiments are being carried out in conjunction with the Experiments Committee of the Bath and West and Southern Counties Agricultural Society. Experimental plots have been started in various parts of the South-West of England, on which the comparative effects of cutting bracken at various times during the season with a view to its extermination are being studied. The experiments are to be continued over three years. The soils of the experimental plots have been analysed in this laboratory. The relative values of pure Nauru Phosphate and high grade Basic Slag for effecting improvement in the herbage of these plots are being compared.

(2) Experiments to ascertain the cause of the dying off of strawberry plants in the Tamar Valley.

These experiments are being carried out in conjunction with other members of the Research Station Staff.

(3) Experiments on Chlorosis with reference to a case at Winscombe, Somerset.

Further experiments have been carried out on tomato plants during the season 1921, but the results of the series are not yet complete. It is hoped that these will be completed during the season 1922, after which a full report will be made on the work done.

(4) Manurial value of certain Radio Active Residues.

Pot experiments have been carried out to test the manurial value of the residues on the growth of mustard and peas.

(5) Agricultural Education Association Experiments on the relative values of various phosphatic manures in improving poor pastures.

The soils of the experimental plots situated in Somerset are being analysed in this laboratory.

(6) Liming Experiments on Acid Soils.

Experimental plots have been started at the Research Station to investigate the meaning of the "lime requirement" figures obtained by the Hutchinson-McClennan Method on a definite soil type. The method of experiment adopted is to determine the lime requirements of various acid plots of the same soil type and to apply various amounts of lime to these and to note the effect of these dressings on the "lime requirement" figures obtained at yearly intervals. It is proposed to carry out experiments along these lines as opportunities occur on the various soil types in the Bristol Province.

Economic Entomology.

The subjects dealt with were as follows :—

Insects	53
Sprays	12
Diseases	13
Fruit Questions	14
Miscellaneous	1

Under the heading "Insects" all other economic groups, such as Myriapoda, Arachnida and Mollusca are included. Among the more interesting fruit insects may be mentioned the Plum and Cherry Borer (*Semasia woeberiana*), and the Raspberry Gall Fly (*Lasioptera rubi*), both sent in from Somerset.

From Worcestershire a request was sent in for identification of a soil insect among newly planted strawberries. This proved to be Leather Jackets that were present in thousands, eating first the leaves, and, finally, the whole plant. Subsequent enquiry showed that the field had been under grass recently. Advice given was to roll the soil as firmly as possible (in this case by means of cart wheels) and then to secure a dust tilth of about two inches. This method has given excellent results in field practice. The case is important since it is obvious that such conditions may occur whenever new strawberry plantations are put down on recently ploughed grass land. So far no information is to hand as to the success of the method in this particular case. Several enquiries were sent in respect of surface caterpillars attacking turnips and swedes. In most cases it was too late to take any active steps. These caterpillars have evidently been widespread this year, and a large acreage has been damaged.

"Diseases" indicates maladies other than those caused by fungi and insect pests. Of these enquiries 10 concerned Reversion Disease of Black Currants, specimens being frequently sent in for identification and advice.

"Fruit Questions" were largely concerned with the subjects of Lorette pruning and of ringing. It is evident that growers are taking an increasing interest in the possibilities of Lorette's system of pruning, and some have already started the treatment on their own plantations. Their results are already sufficiently promising to ensure the system being given a fairly extensive trial in the next 10 years. The operation of "ringing" has also been the subject of considerable enquiry, both verbal and through the post.

The number of enquiries has shown an increase of 33 per cent. on last year's figures. This figure does not probably do full justice to the amount of advice asked for, since much is given by word of mouth on various occasions, such as Growers' Meetings, the Field Day of the Research Institute, at Shows, and in the course of ordinary visits to growers' plantations. There is no doubt that the call for advice is increasing rapidly as the grower realises the value of the research work that is being done. There is every likelihood of this call for advice increasing in intensity, and in the near future of still further encroaching on the time at present available for research.

Visits.

Pershore.—The Pershore Market Gardeners' and Fruit Growers' Association expressed a desire for a visit of Advisory Officers on two occasions. Mr. Wallace and I accordingly spent several days in the Pershore district in November, 1920, and Mr. Wiltshire and I in the Spring of 1921. The visits revealed certain problems, some of a mycological, some of an entomological, but most of them of a pomological nature.

Cox's Orange Pippin not Fruiting.—Of this there were two cases. The first was an arable orchard containing 15-year-old Cox bushes on paradise stock. There were also present as pollenisers, James Grieve and Worcesters. The orchard went down to rough grass during the war, and was in that condition at the time of visiting. There was a certain amount of Psylla eggs on the trees, but not a large number. The Cox Orange Pippin flowered abundantly and there were plenty of bees about. Occasionally branches, and occasional trees would set fruit, but a full crop was never obtained. Cox on free-stock in grass in a neighbouring orchard fruit well. The reason for non-setting could not be due to lack of polleniser or bees, because these were present, nor to the grass, because no set was obtained years ago when the culture was clean. It could not be due to Psylla, as there was not sufficient eggs present to account for damage to bloom. Nor could it be due to frost, as the other varieties set satisfactorily. A further search revealed the fact that the spurs were all weak and mostly three-leafed. It appeared, therefore, that the failure was due to lack of food.

Investigations by Mr. Wallace showed that the soil was heavy (Lower Lias), and had a slightly acid re-action. The trouble was attributed by him tentatively to lack of nitrates in the soil. Experiments have been suggested by him to test the effect of dressings of lime and nitrogenous manures.

A second case of Cox Orange Pippin not fruiting properly was also met with in the same district. Here again the circumstances were very similar, and nitrogenous manures were advised. The trees have improved in general appearance under the treatment and may show results in fruiting next year.

In a third case, Cox was one of several varieties that did not fruit as expected and desired. These trees were next to Beauty of Bath. Plenty of spurs were present, but they were all weak. Mr. Wallace reports that this soil was a very heavy one, containing a high percentage of clay and a large supply of lime, but that phosphates were deficient. It is probable that they require heavy dressings of nitrogenous and phosphatic manures.

These three cases have all this feature in common—that apples were flowering abundantly, but not fruiting, though every conceivable need is supplied, except, possibly, the manurial one. Observation and evidence lead me to think that this limiting factor is a comparatively common and usually unrecognised one in plantations where trees have attained 10 to 15 years of age.

The Poor Fruiting of Rivers' Early Prolific Plum.—This plum, despite its name, is not prolific in Worcestershire. Roughly speaking it gives a good crop once in seven years, a poor to medium twice in seven years, and practically no crop at all in the other four years. A case of this kind was advanced by one grower, who stated that his trees now 25 years old, fruited but poorly. He further stated that cut back bushes would fruit though fairly young ones, uncut back, do not. These facts appear to indicate that these trees are suffering from nitrogen shortage (even though good fruiters, such as Pershore Plum, would set under these conditions). Mr. Wallace has suggested to this grower experiments with nitrogenous dressings.

Black Currant Culture.—Though this fruit is not abundantly grown, in most cases where it is grown the stocks were distinctly, sometimes very much, affected with Big Bud. Reversion was also correspondingly present. Seabrook's Black is more susceptible to Big Bud than in East Anglia, though, probably, not so much so as at Long Ashton. The importance of obtaining clean stocks did not seem to be sufficiently realised.

Leaf Scorch of Apples.—One plantation visited on the "Drift" soil of the district was suffering from a rather severe case of leaf scorch. Mr. Wallace reports that an examination of other fruit plantations on this deposit has shown that the disease is present on apple trees in all these plantations. The cause of the scorching

on this soil is being studied in the investigation on Leaf Scorch now in progress at Long Ashton. Analysis shows that the soil is of a very coarse texture, containing a high percentage of gravel and sand and is deficient in potash. The effect of applying a dressing of potash to the soil is being tried.

Newnham-on-Severn.—An application to demonstrate Lorette's pruning was made by a grower in this region. The demonstration was given, and after half an hour of theoretical and practical instruction some 10 or so of his pupils were able to do the necessary work quite efficiently. The method is, therefore, easily taught to persons of intelligence.

A visit to a neighbouring plantation showed Pershore Plums doing badly, though Warwickshire Hangdowns were making good growth. Many of the spurs on the Pershores were dying, and the trees looked unhealthy. The soil was distinctly acid and the trees were, therefore, probably short of nitrogen (as their appearance led me to believe). The weaker growing Pershore showed the effects far more than the stronger growing Hangdown.

Street, Somerset.—A visit was made to this district with Mr. Turner, Horticultural Instructor for the County, for the purpose of giving advice on pruning and matters of general importance in fruit culture. The district is a striking one from the fruit point of view in that apples are making good but short and sturdy growth on a heavy Lias soil in a wet district. In the same rainfall and a lighter soil at Long Ashton, this short sturdy growth cannot be obtained. One striking point about soil conditions in the Street district was the presence of Lias Limestone about four feet below the surface. It is at least probable that the presence of this stone has a growth-limiting action in summer which opposes the usual growth-hastening action of the high rainfall. There are at present only a few growers in this district, but in my opinion it is one where apple growing should succeed in bush form.